# Improving forecasts of crop water demand with direct ET measurements over irrigated fields

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# Acknowledgements


- Ammara Talib, UW-Madison Civil and Environmental Engineering
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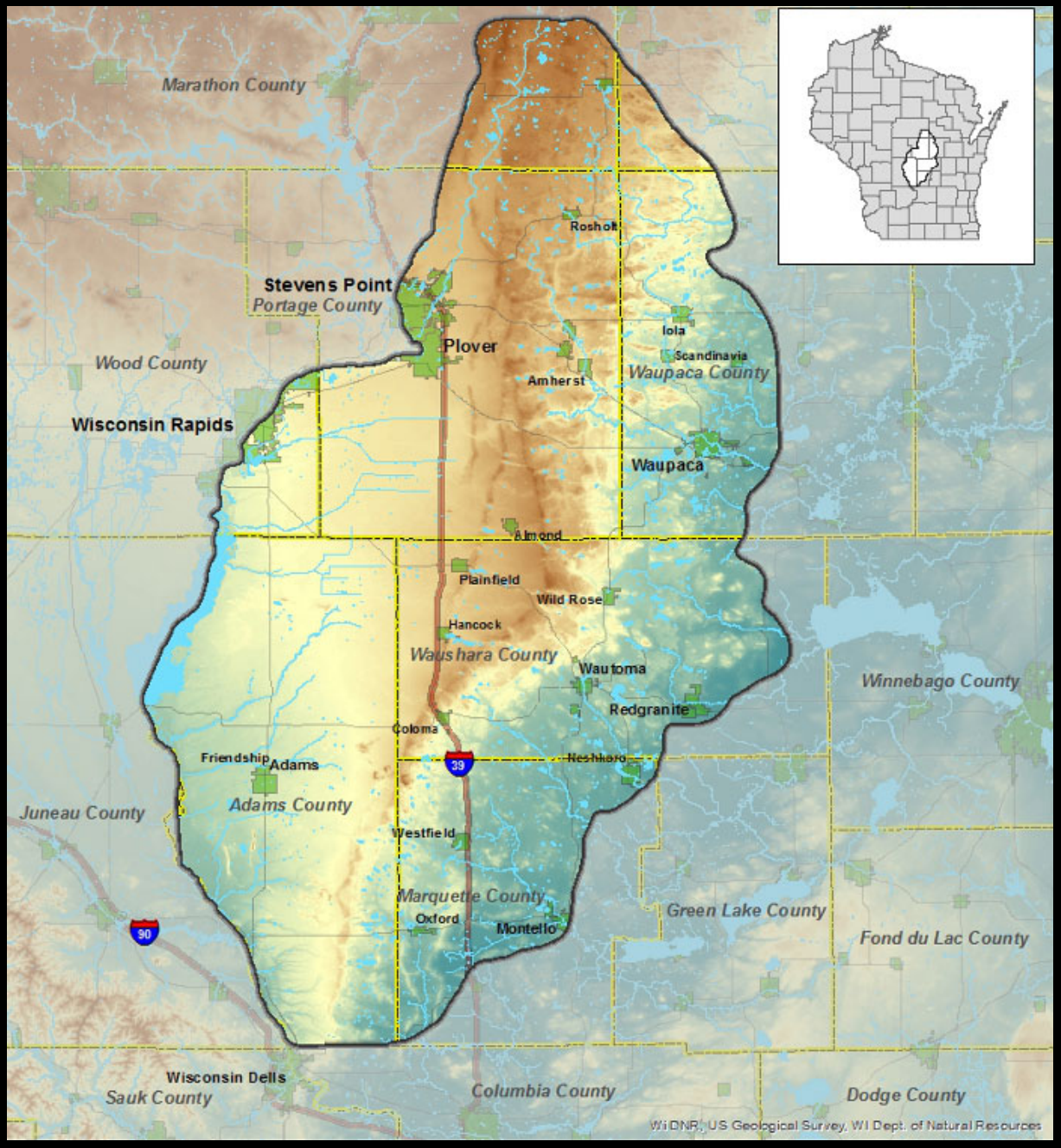
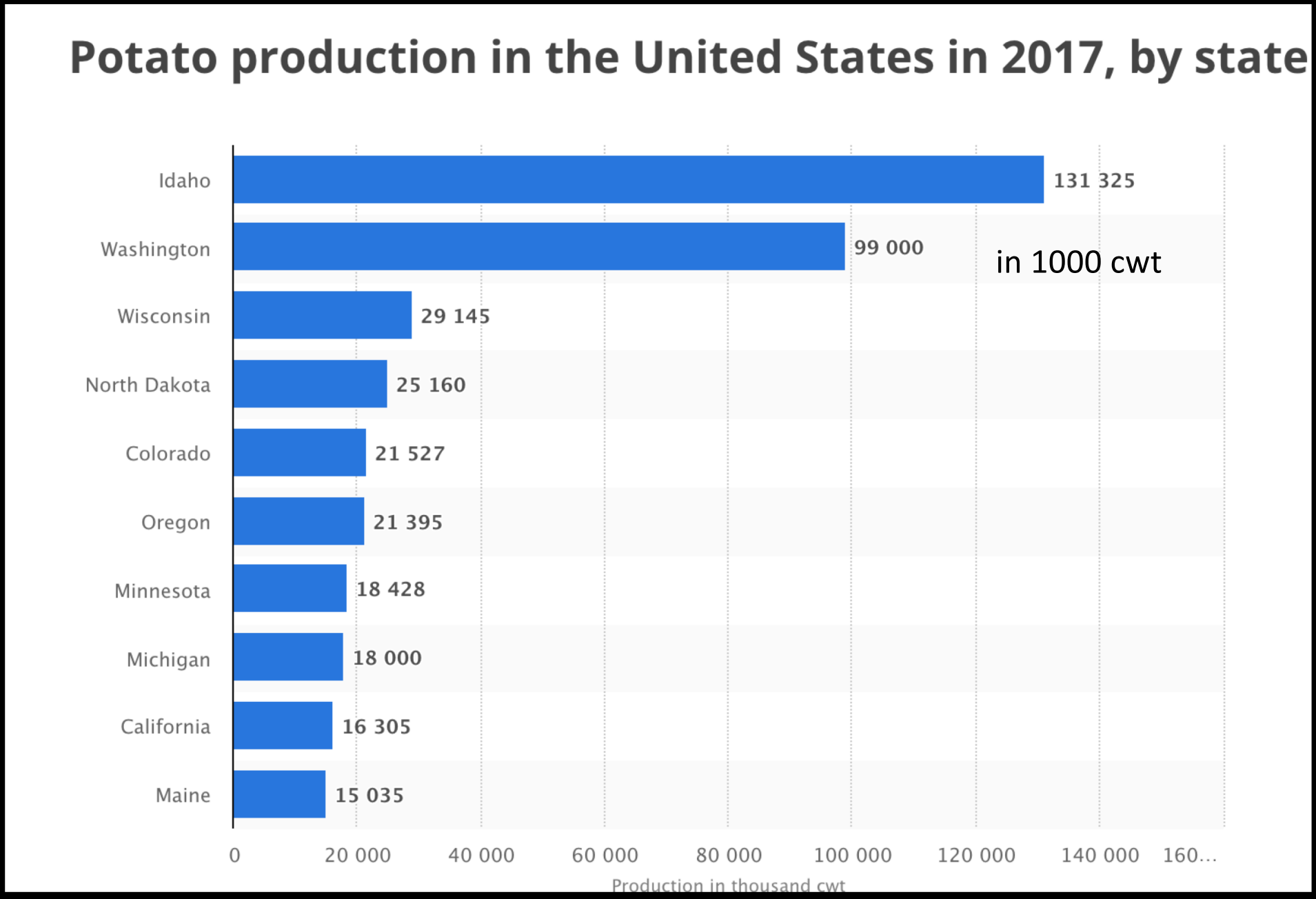
- Yi Wang, UW-Madison Horticulture
- Chris Kucharik, UW-Madison Agronomy
- Steve Loheide and Dom Ciruzzi, UW-Madison Civil and Environmental Engineering

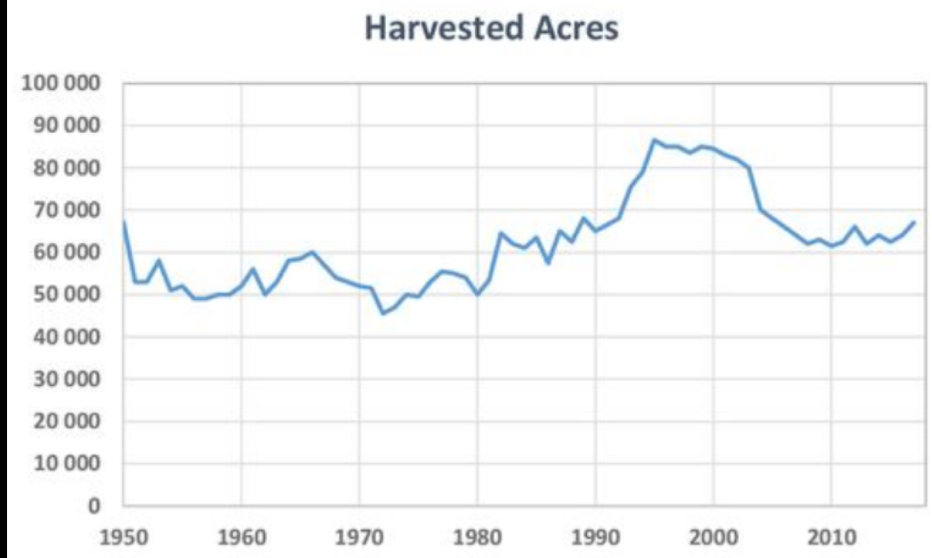


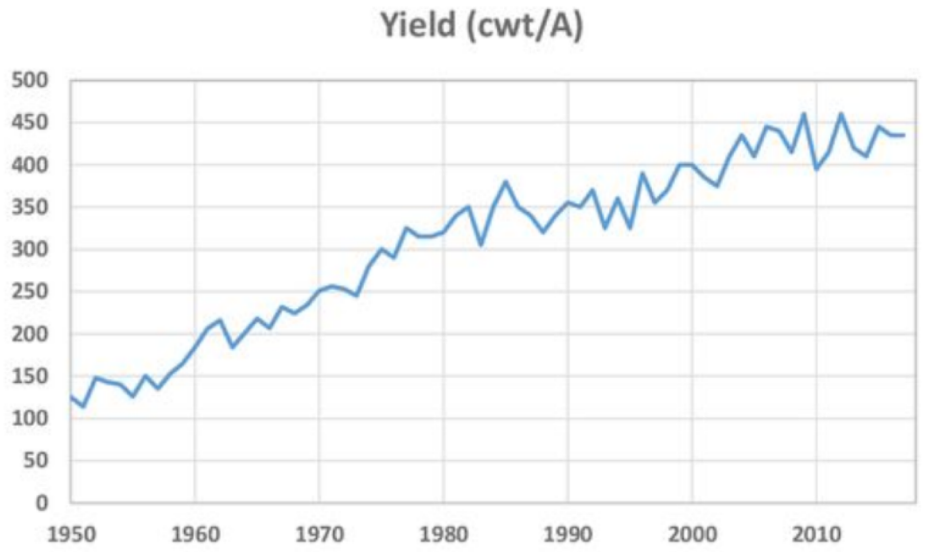

https://dnr.wi.gov/topic/Wells/HighCap/CSLBackground.html

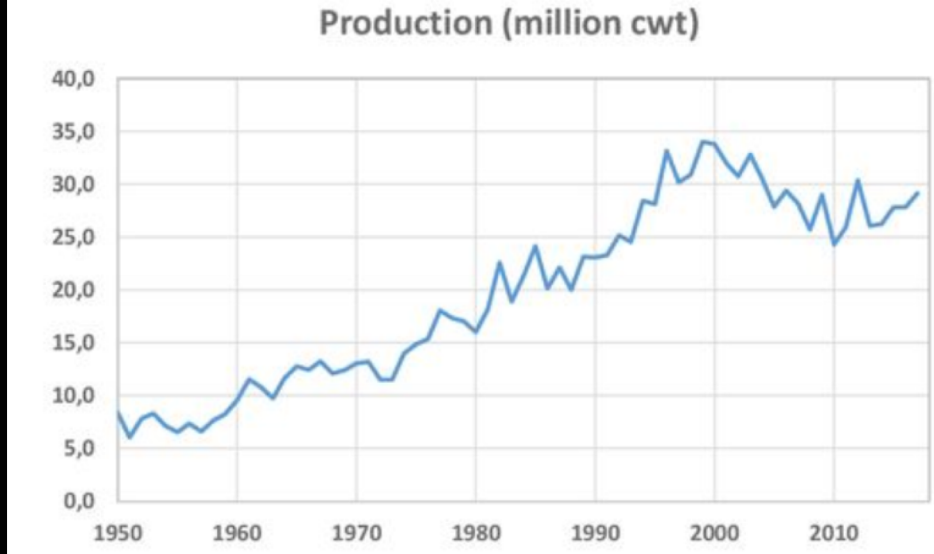


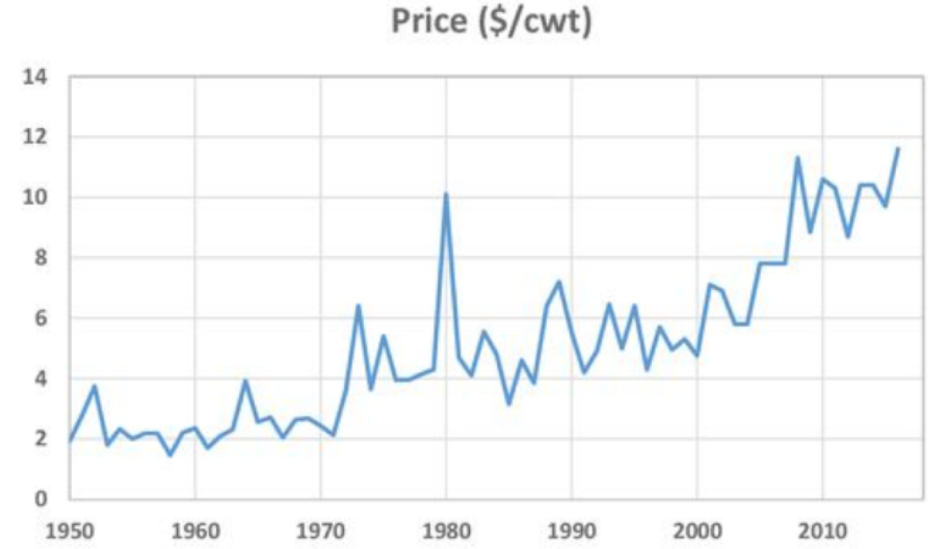

https://www.statista.com/statistics/382166/us-potato-production-by-state/

# Potatoes in Wisconsin Since 1950



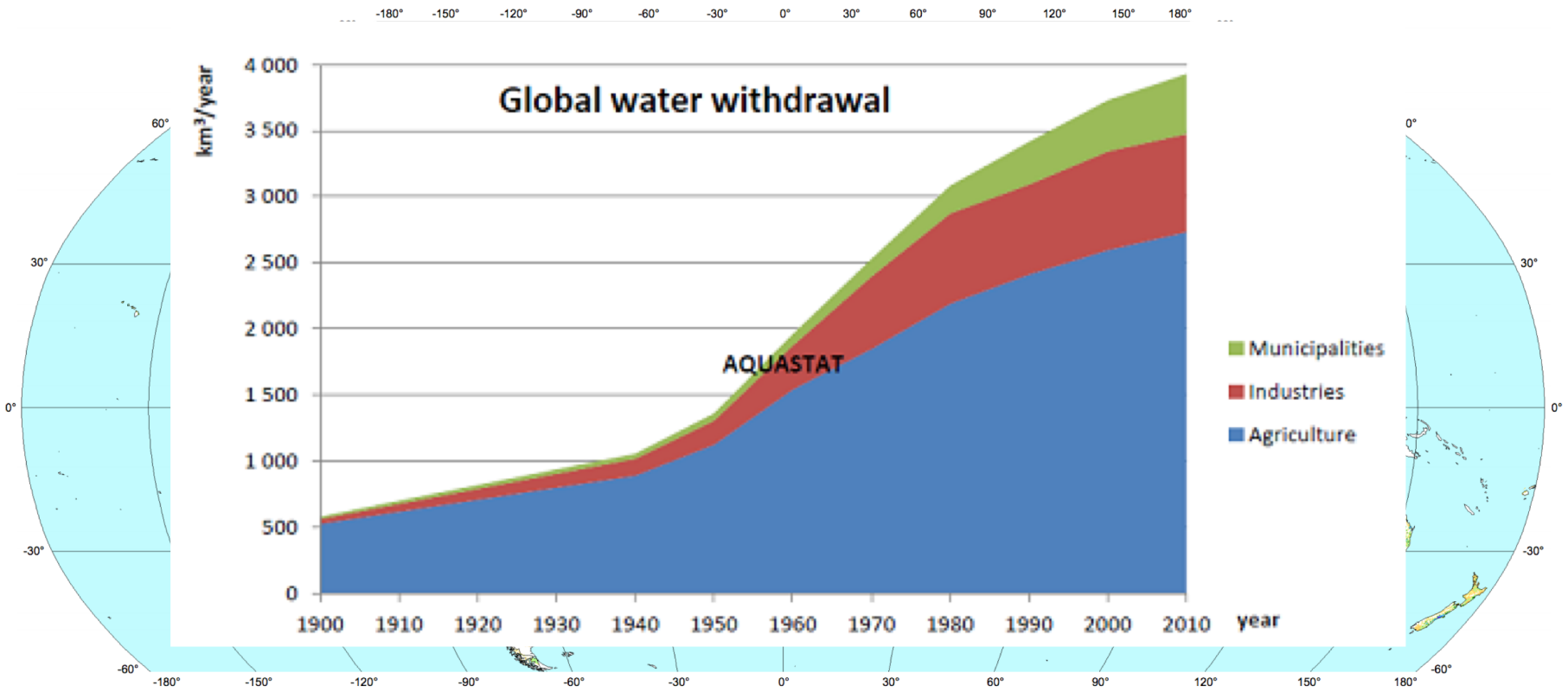




Paul Mitchell, UW-Madison, https://slideplayer.com/slide/14100644/

# The digital global map of irrigation areas

## October 2013




**Area equipped for irrigation in percentage of land area**

| | |
|---|---|
| 0 | 10 - 20 |
| < 0.1 | 20 - 35 |
| 0.1 - 1 | 35 - 50 |
| 1 - 5 | 50 - 75 |
| 5 - 10 | 75 - 100 |

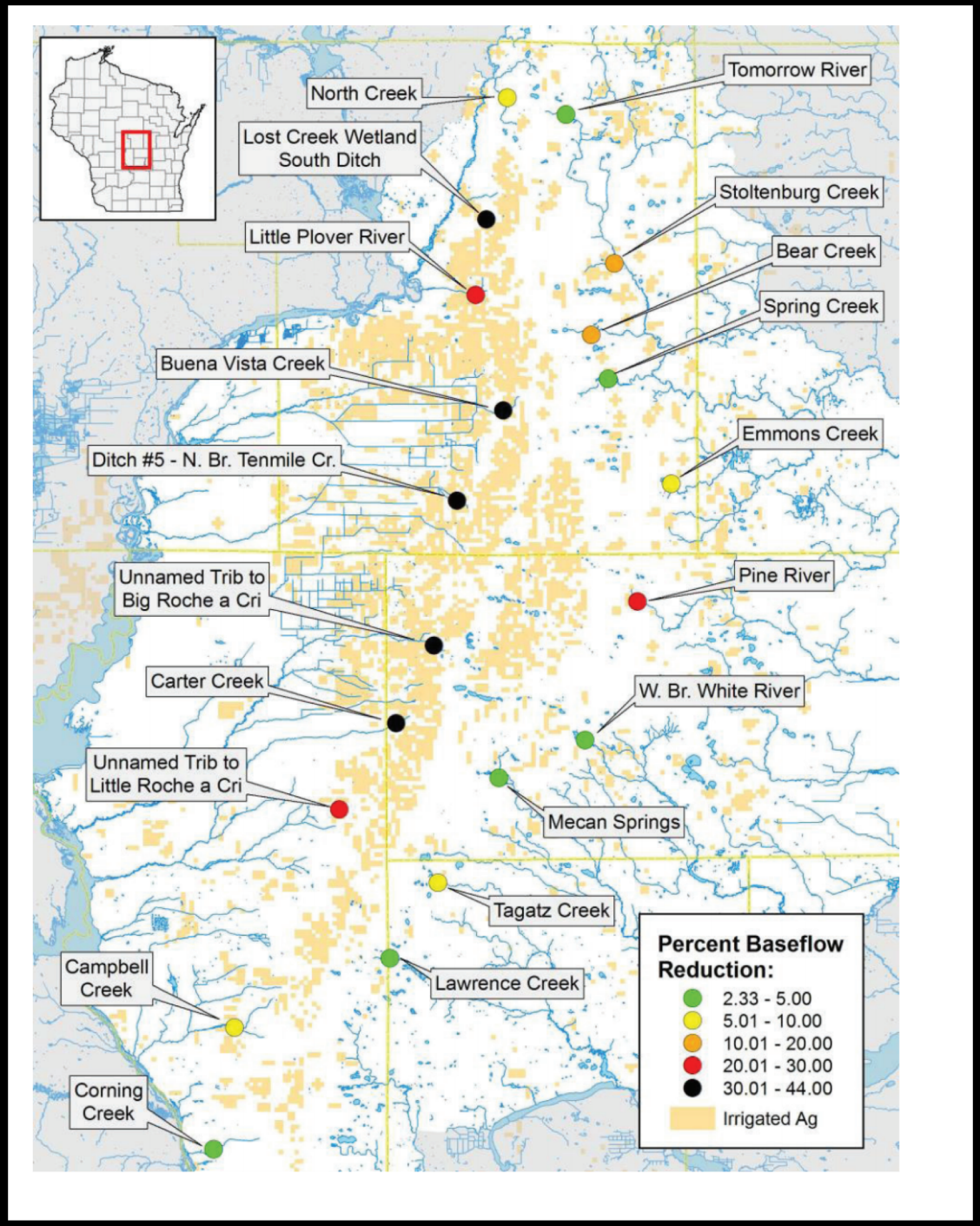
The map shows area equipped for irrigation in percentage of cell area. For the majority of countries the base year of statistics is in the period 2000 - 2008.

Projection: Robinson
Resolution: 5 arc-minutes

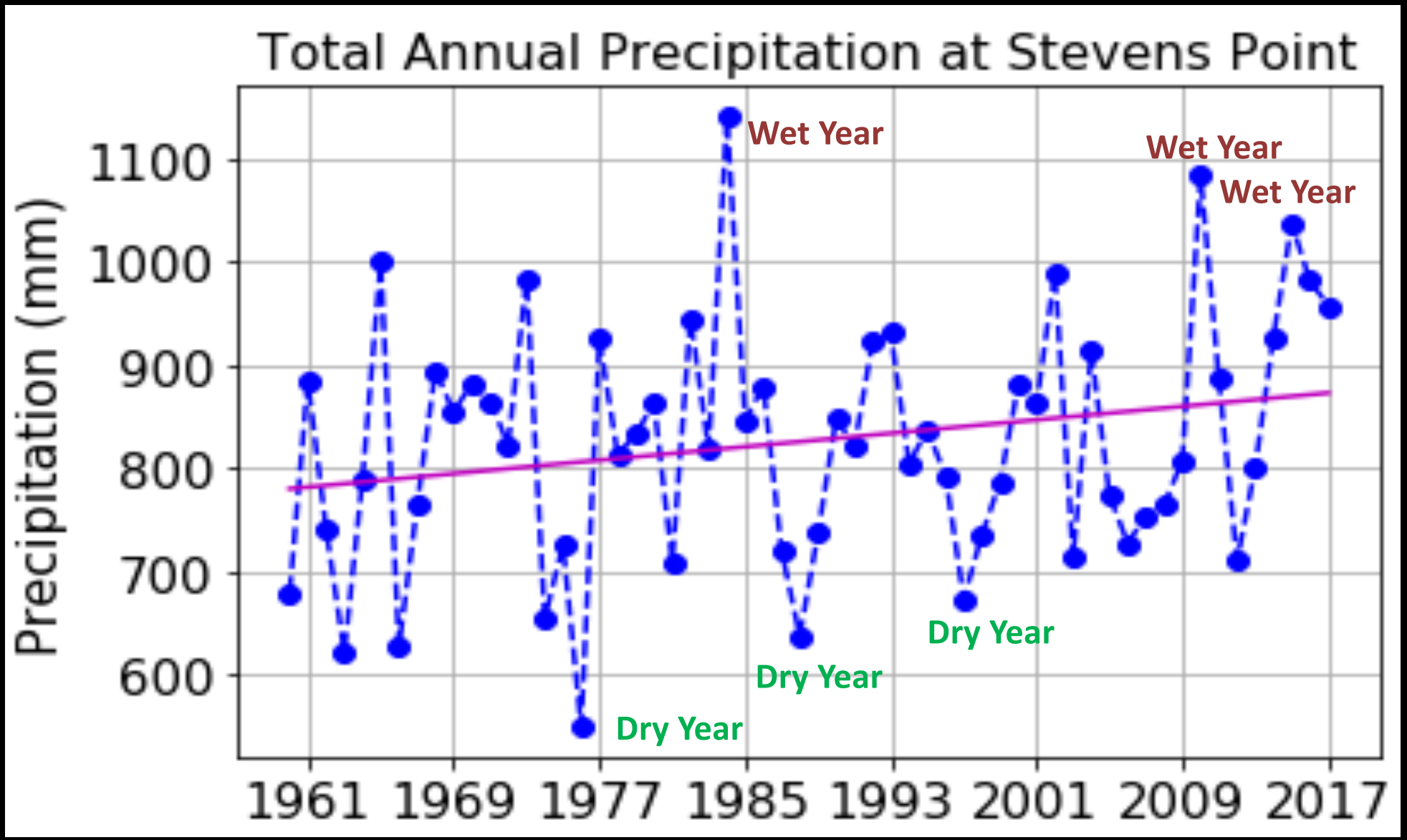
http://www.fao.org/nr/water/aquastat/irrigationmap/index.stm

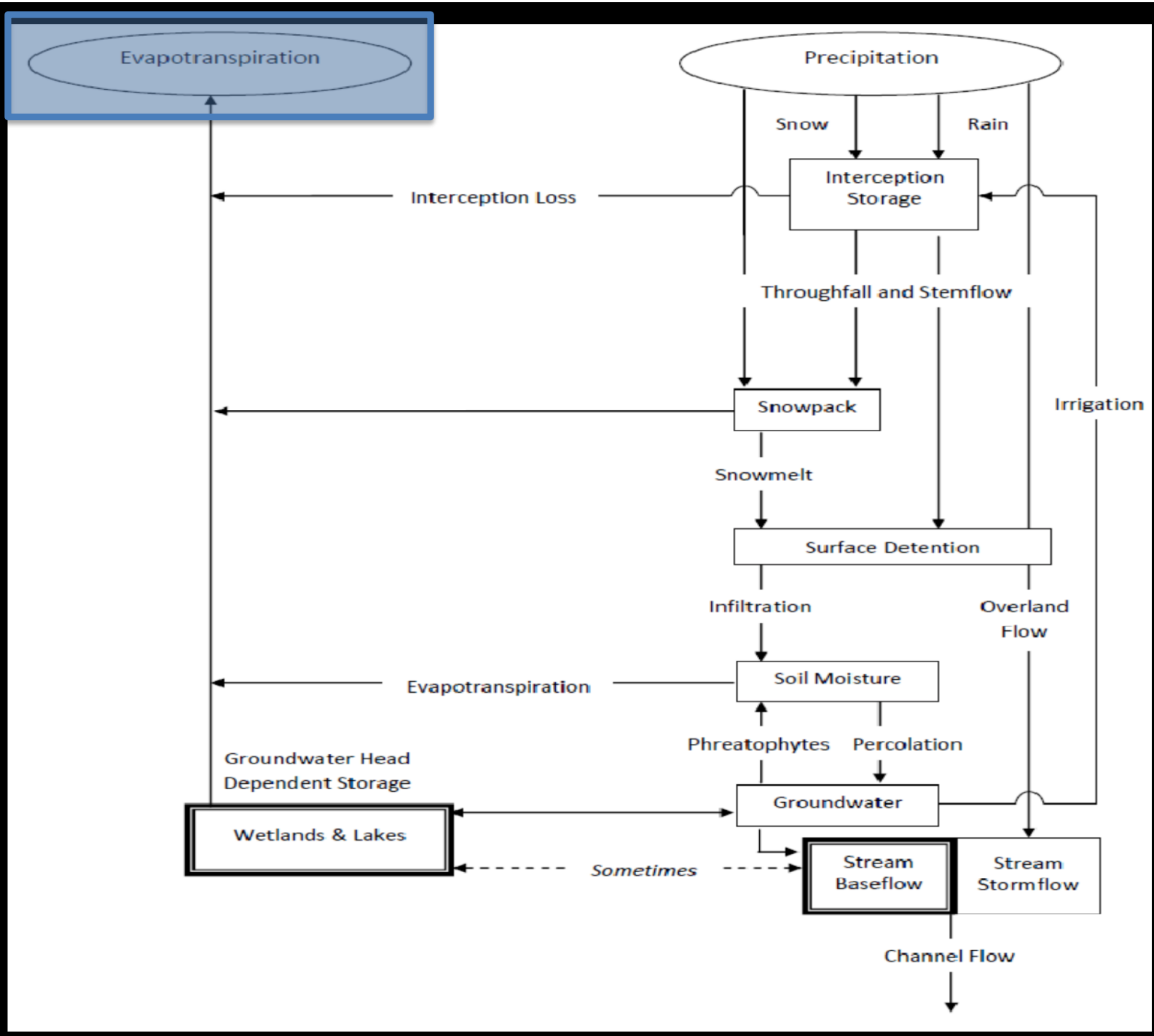
Stefan Siebert, Verena Henrich (Institute of Crop Science and Resource Conservation, University of Bonn, Germany) and
Karen Frenken, Jacob Burke (Land and Water Division, Food and Agriculture Organization of the United Nations, Rome, Italy)

universitätbonn




Kniffin et al., 2014. Sustaining central sands water resources, UW-extension


Total Annual Precipitation at Stevens Point
Precipitation (mm)
1100
1000
900
800
700
600
1961
1969
1977
1985
1993
2001
2009
2017
Wet Year
Wet Year
Wet Year
Dry Year
Dry Year
Dry Year




WICCI Central Sands Hydrology Working Group, 2011

Can we better quantify
evapotranspiration (ET)
to improve understanding of
Central Sands water cycle
and improve
irrigation demand forecasting?

# Ways to measure ET

- Meteorological approximations: Thornthwaite, Priestly-Taylor, Penman-Montieth
  - Strong assumptions on surface properties, ET driven by radiation
- Residual: Measure precipitation, soil moisture, runoff, back out ET
  - Subject to high uncertainty
- Lysimeters
  - Labor-intensive, small-area estimate
- Remote sensing
  - Assumptions on links between electromagnetic radiation and ET, satellites don't work with clouds
- Process models
  - Captures all aspects but requires extensive, hard to measure parameters
- Eddy covariance
  - Direct method, whole field, expensive and expertise required
- Machine "Learning"
  - Site-specific, hard to extrapolate or interpret, but powerful for forecasting

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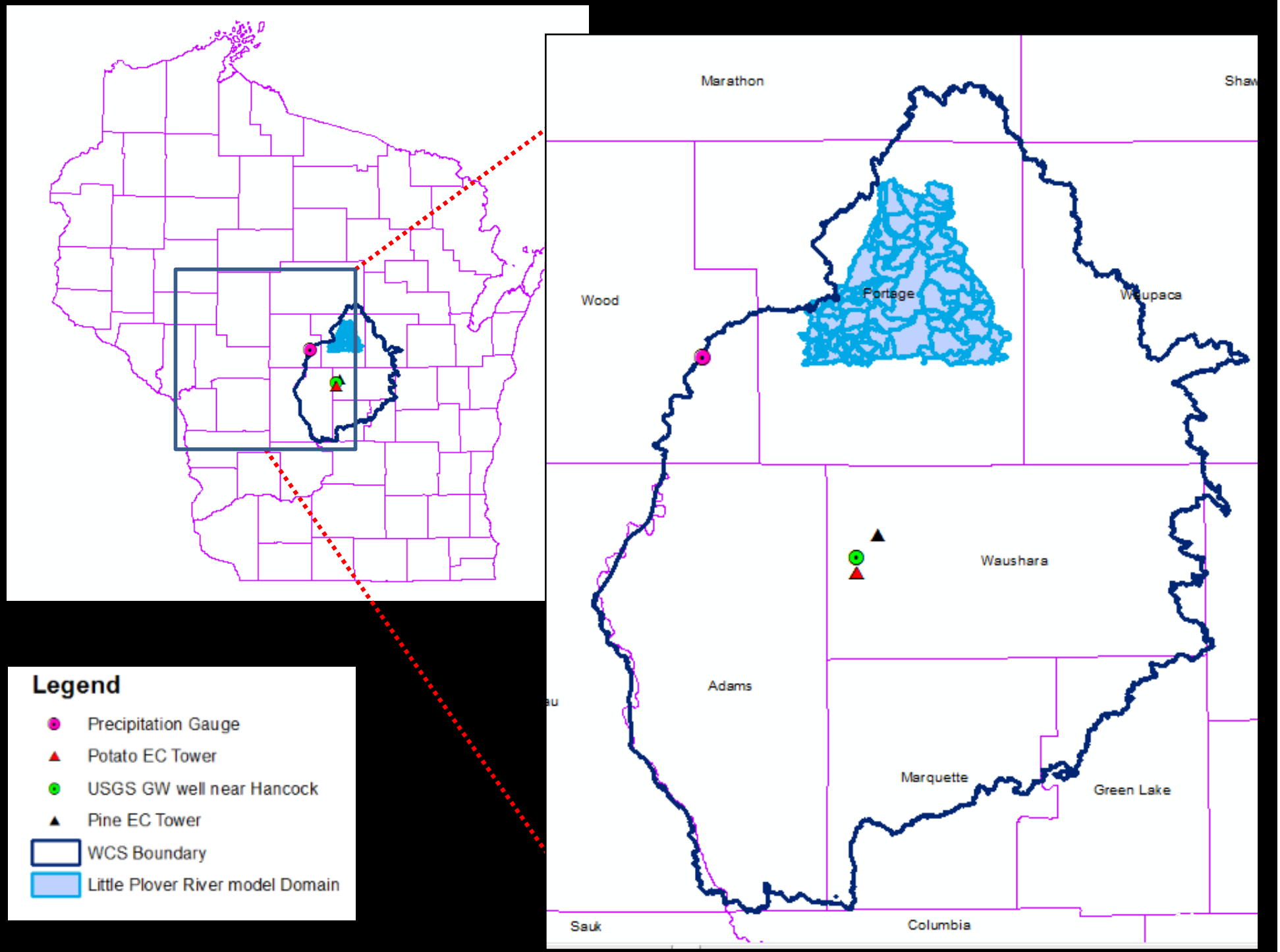
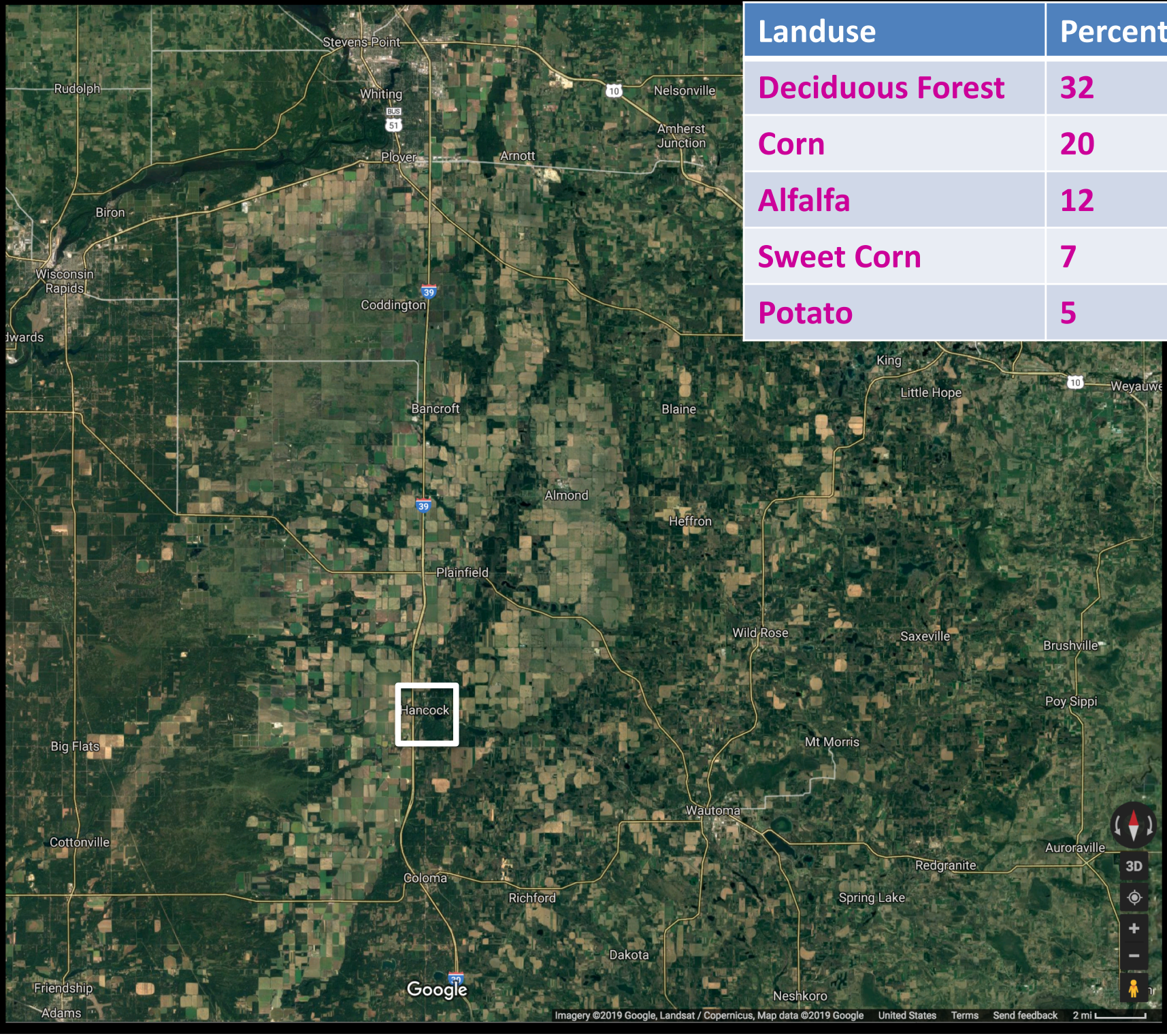
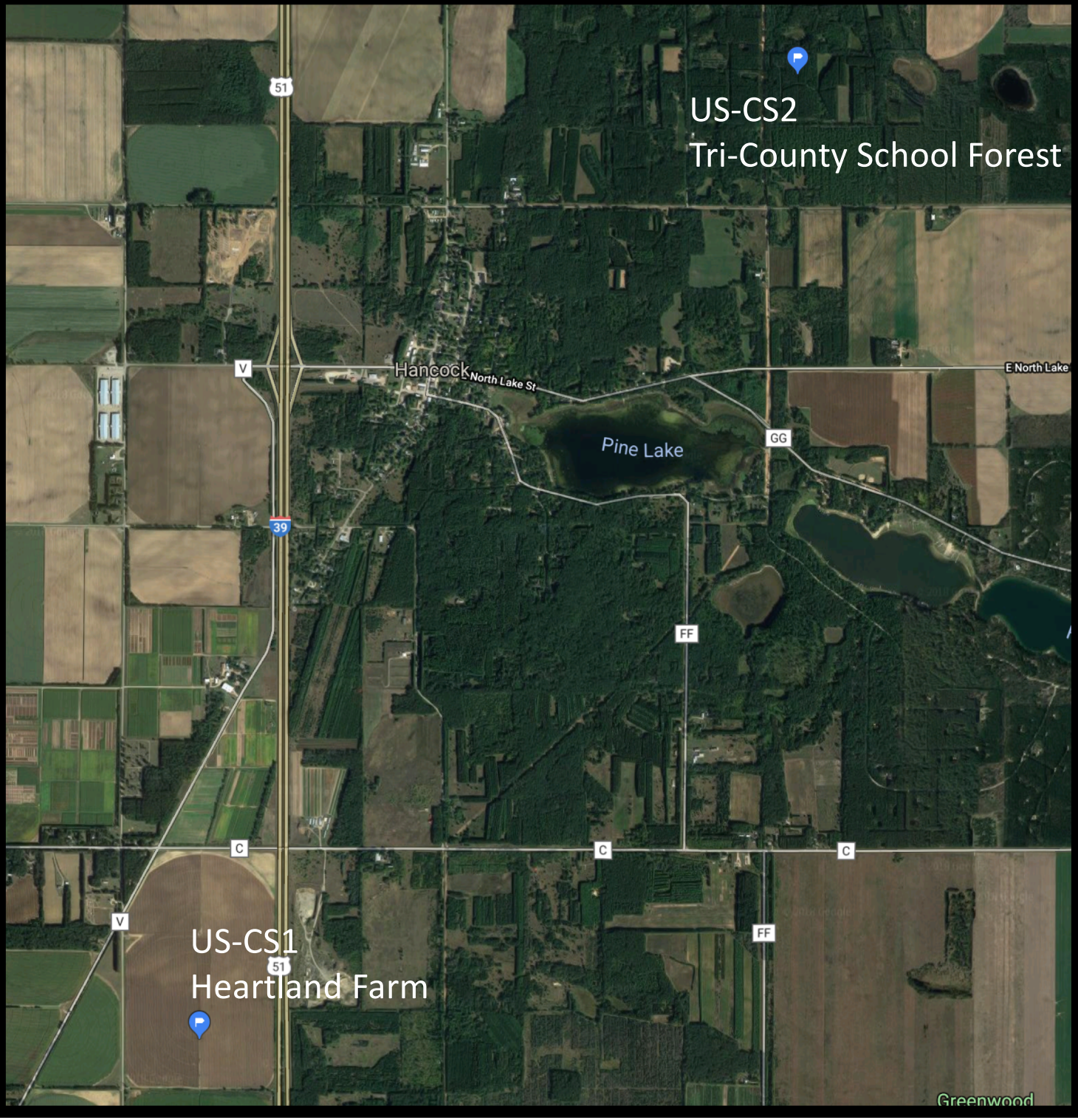
# Eddy Covariance
# “Flux Towers”


Marathon
Wood
Portage
Waupaca
Waushara
Adams
Marquette
Green Lake
Sauk
Columbia
Legend
Precipitation Gauge
Potato EC Tower
USGS GW well near Hancock
Pine EC Tower
WCS Boundary
Little Plover River model Domain

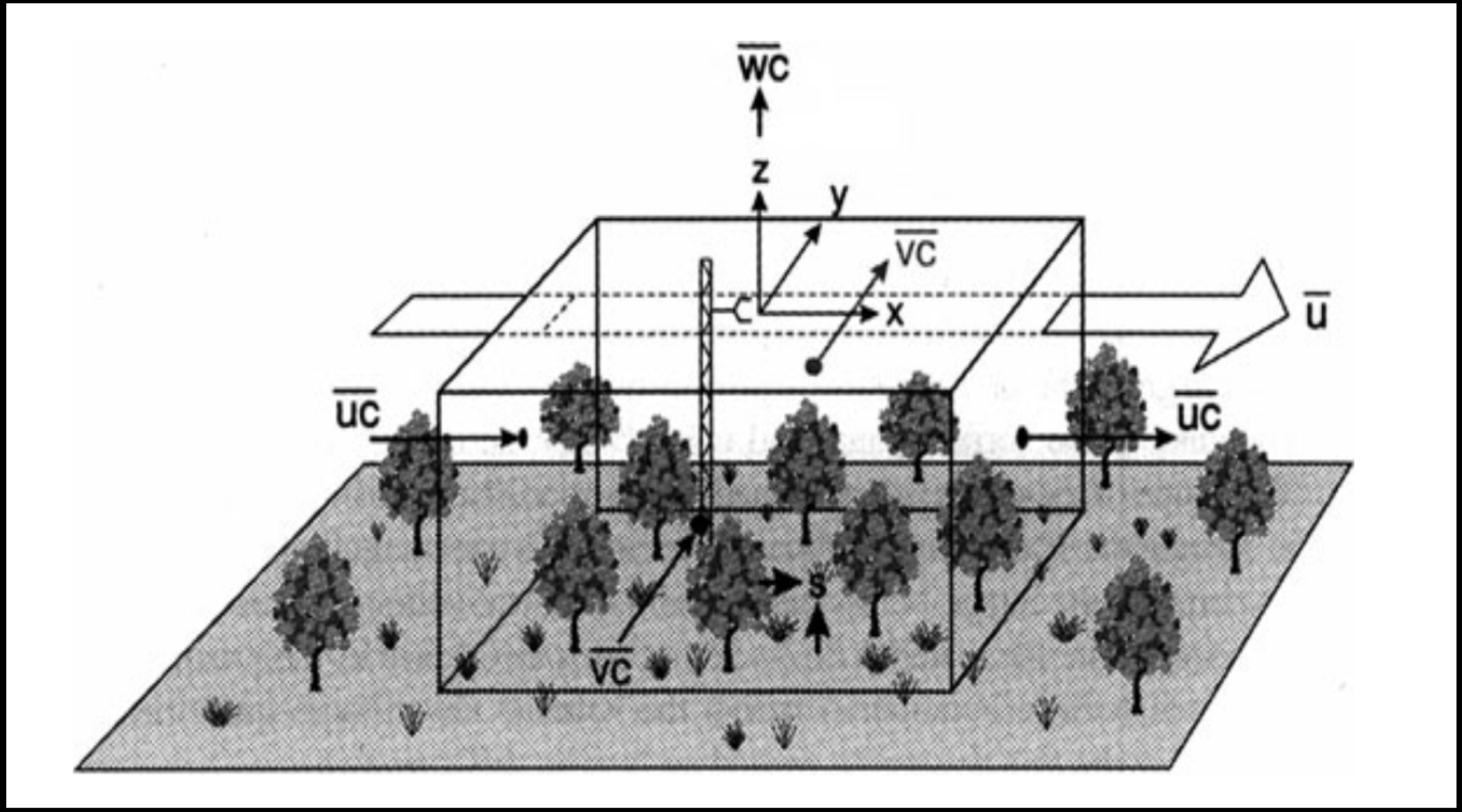



| Landuse | Percentage |
|---|---|
| Deciduous Forest | 32 |
| Corn | 20 |
| Alfalfa | 12 |
| Sweet Corn | 7 |
| Potato | 5 |

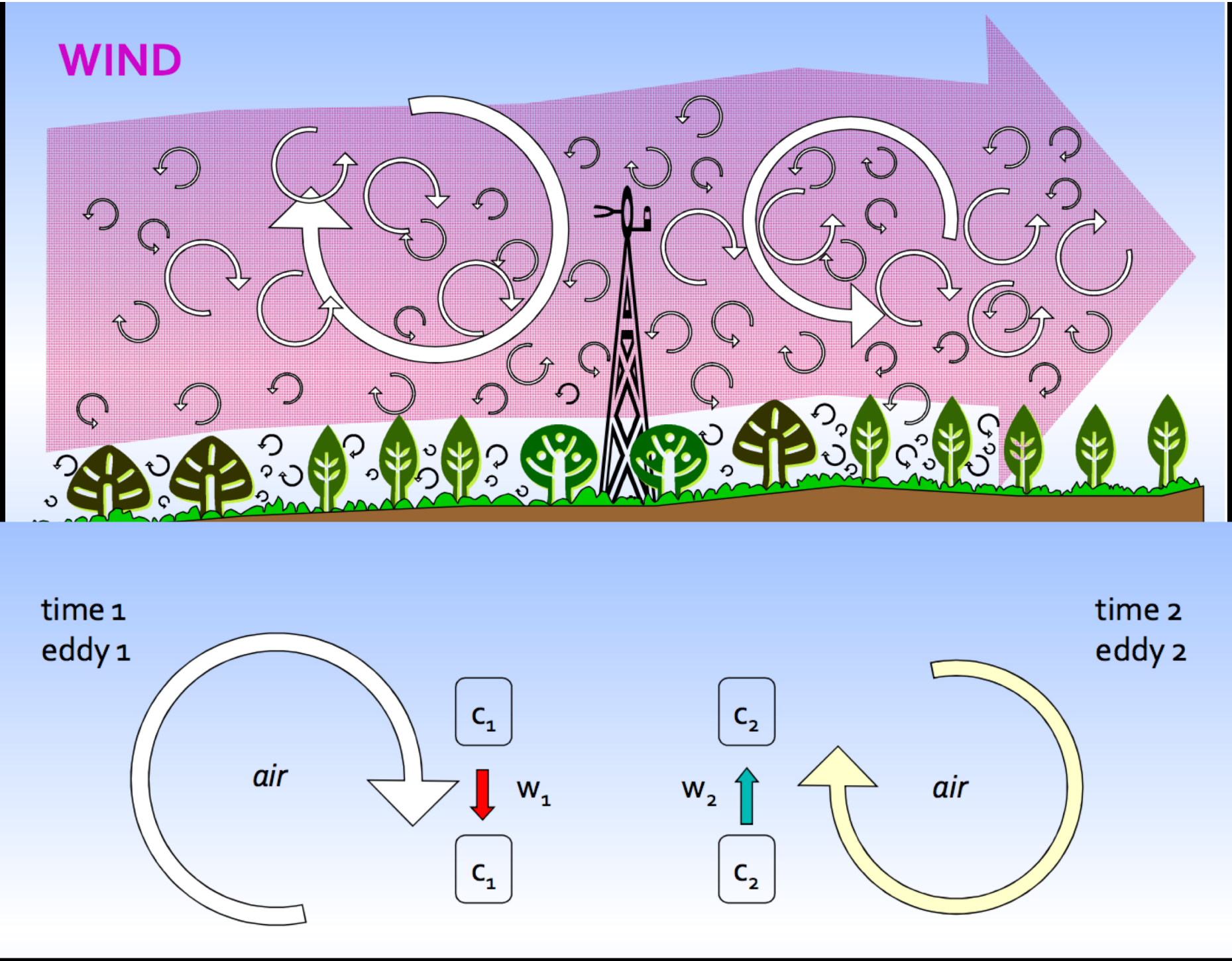

US-CS2
Tri-County School Forest
US-CS1
Heartland Farm
Hancock
North Lake St
E North Lake
Pine Lake
51
39
V
GG
FF
C
Greenwood


US-CS1
Heartland Farm
Operating from Jun 30, 2018
DELTA

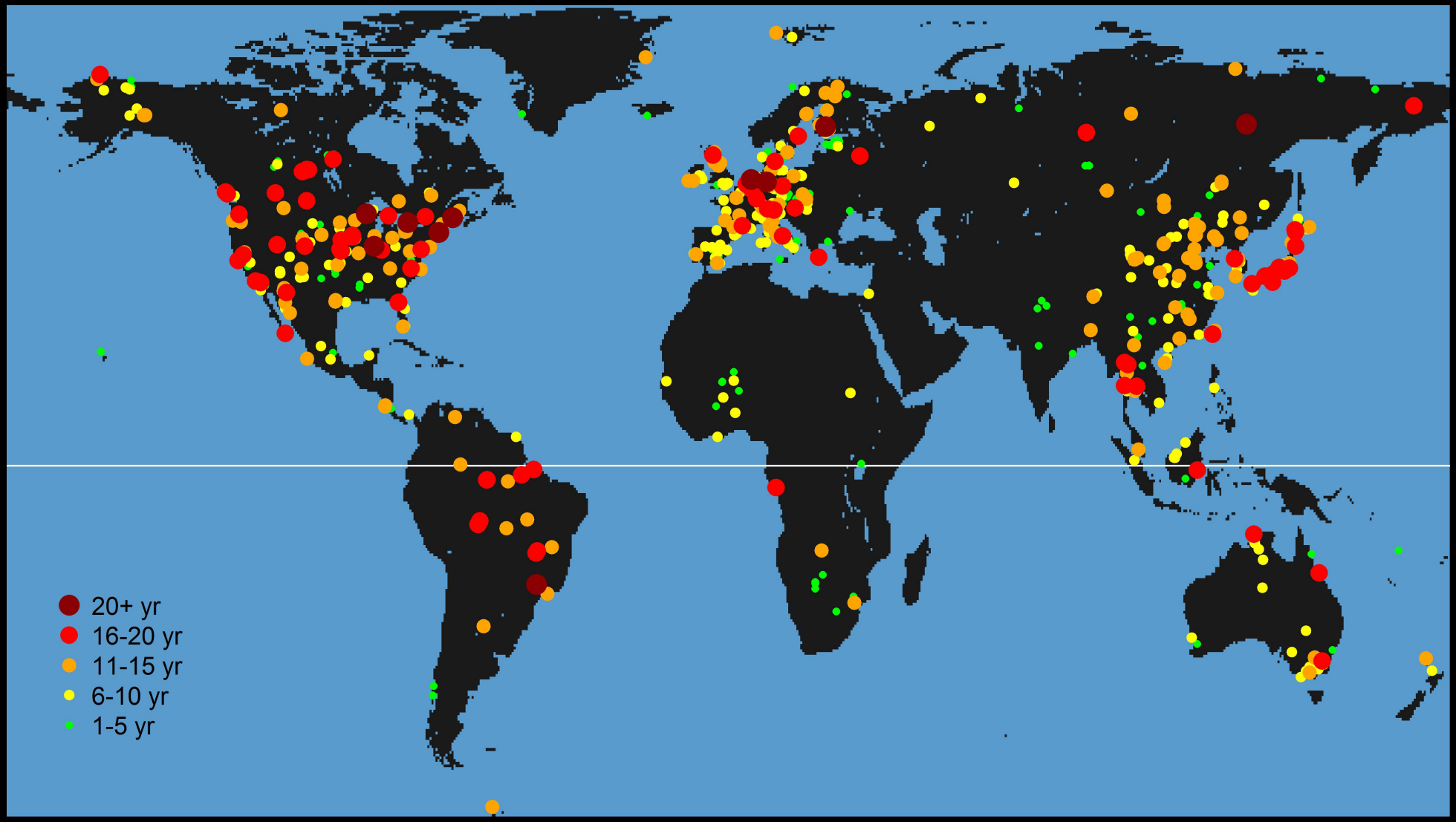
**US-CS2 Tri-County School Forest**
**Operating from October 12, 2018**



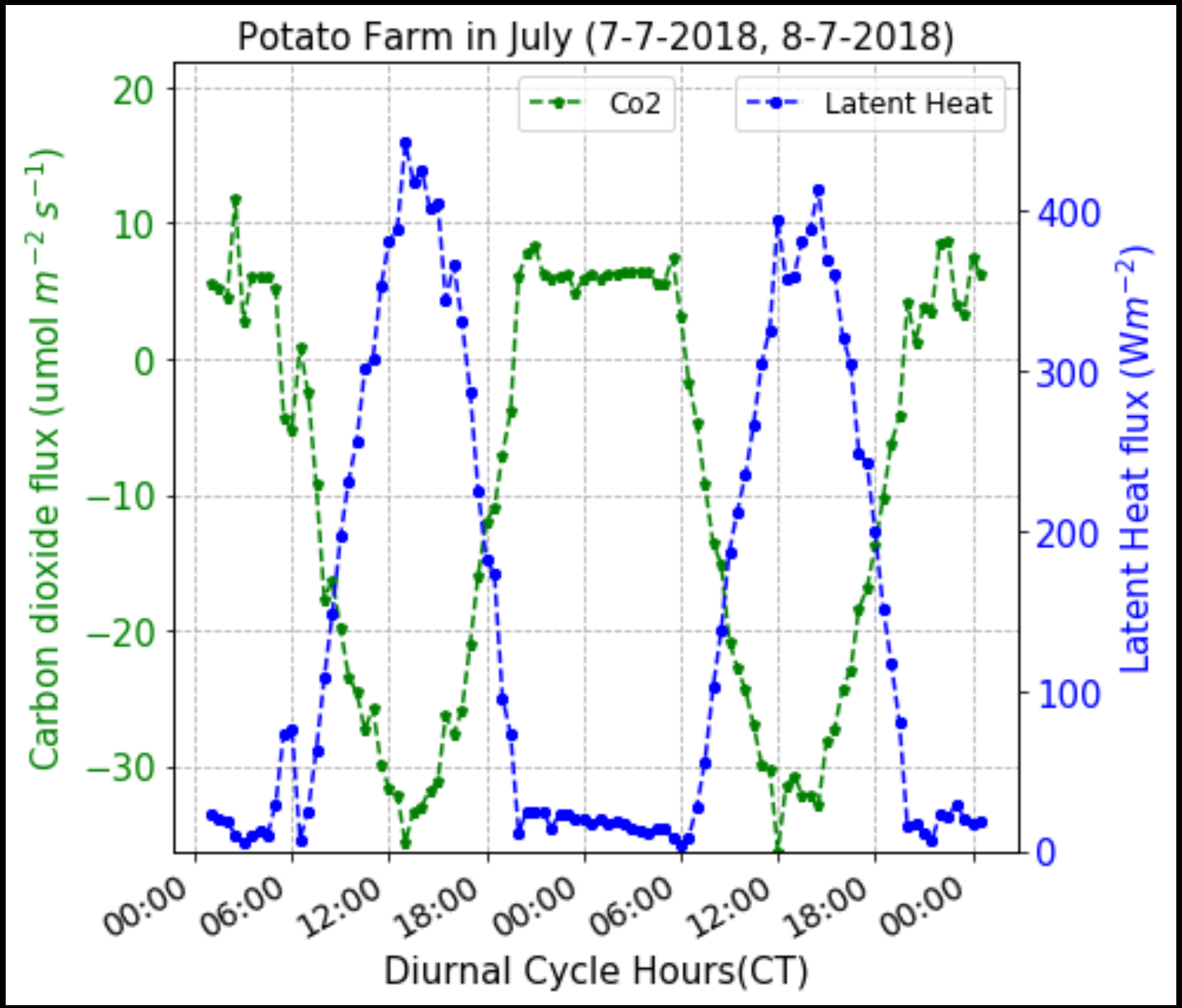

Finnigan et al (2003)




Burba and Anderson (2010)

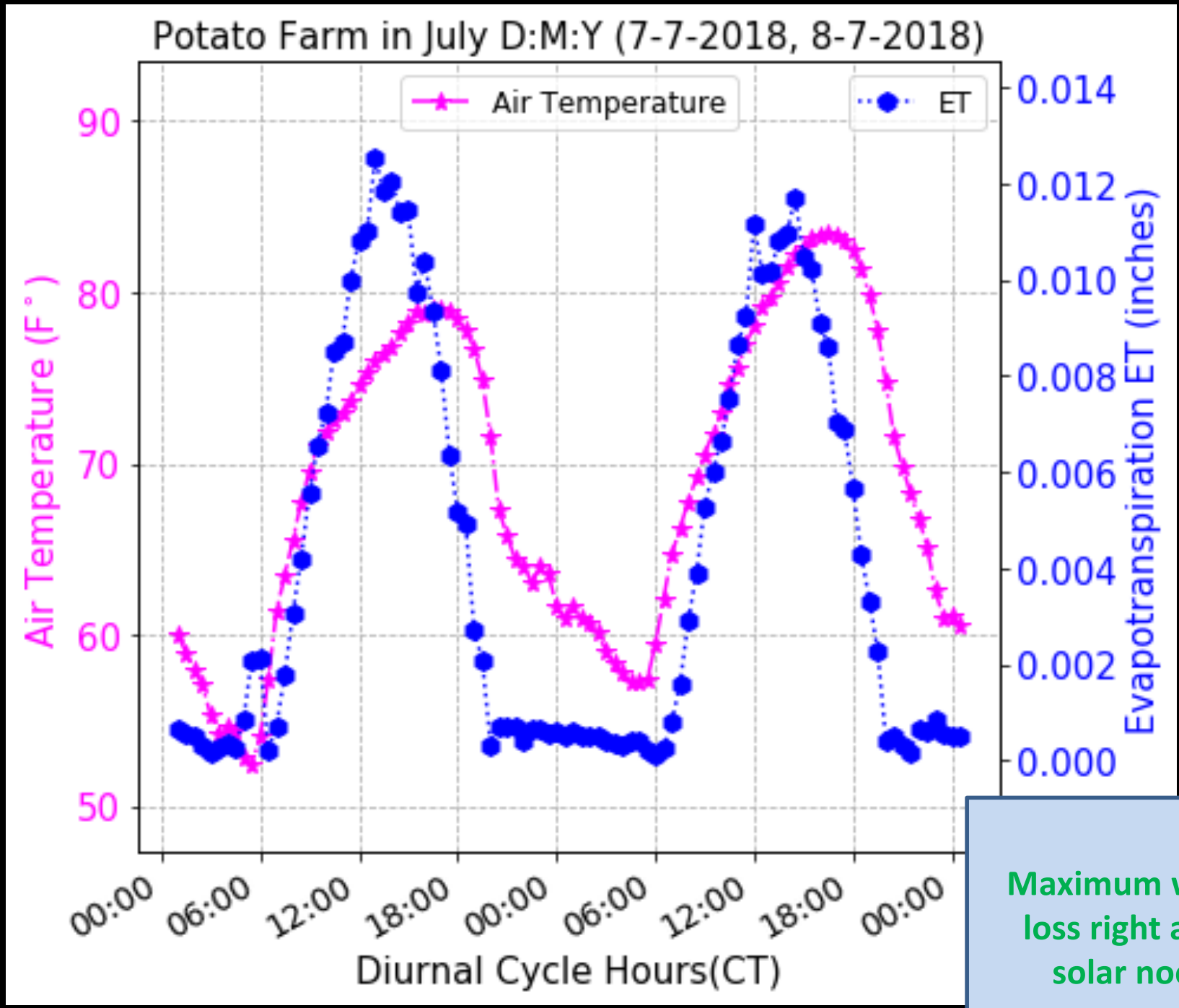



“Fluxnet”

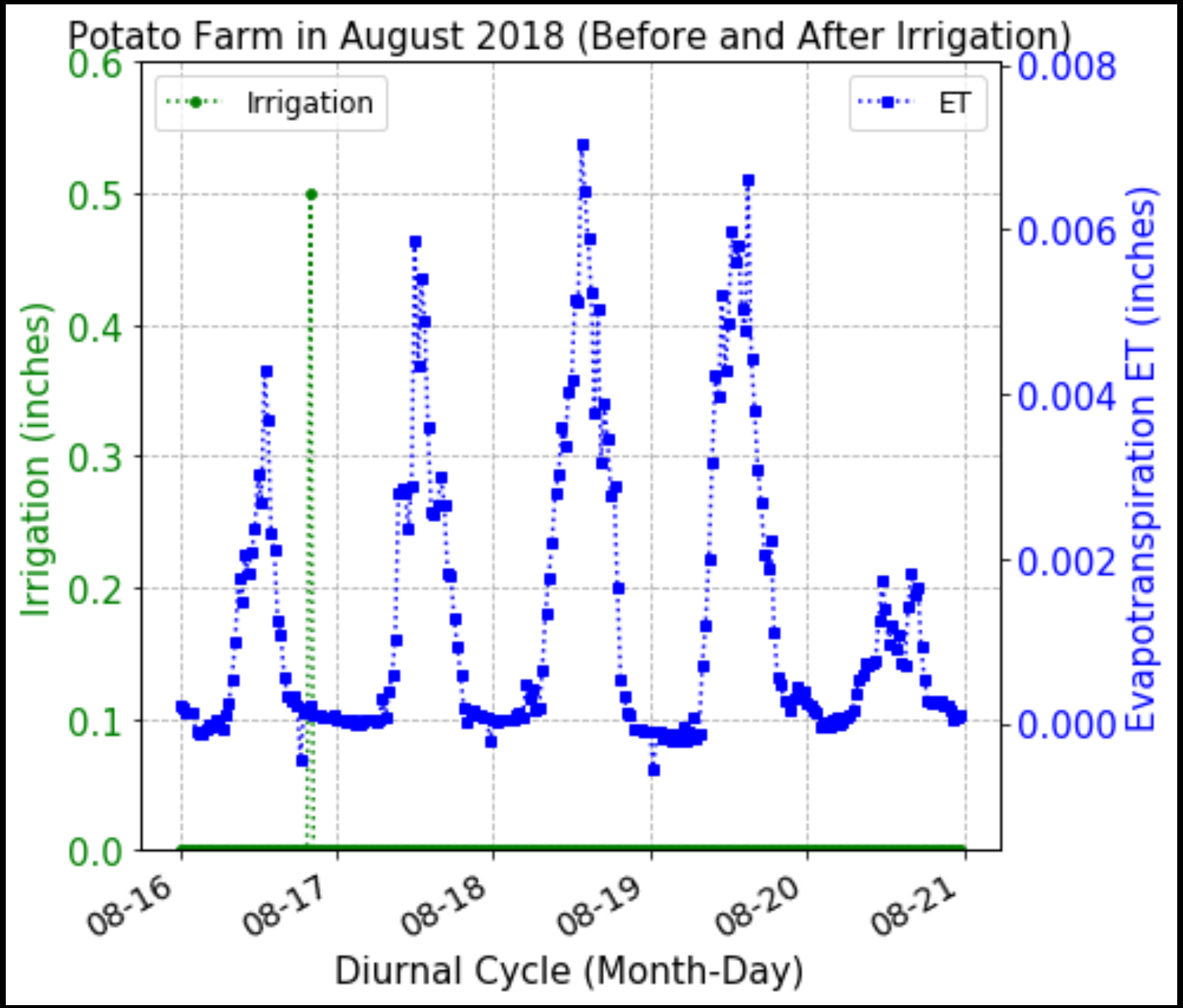

Potato Farm in July (7-7-2018, 8-7-2018)
Co2
Latent Heat
Carbon dioxide flux (umol $m^{-2}$ $s^{-1}$)
Latent Heat flux ($Wm^{-2}$)
20
10
0
−10
−20
−30
400
300
200
100
0
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
Diurnal Cycle Hours(CT)

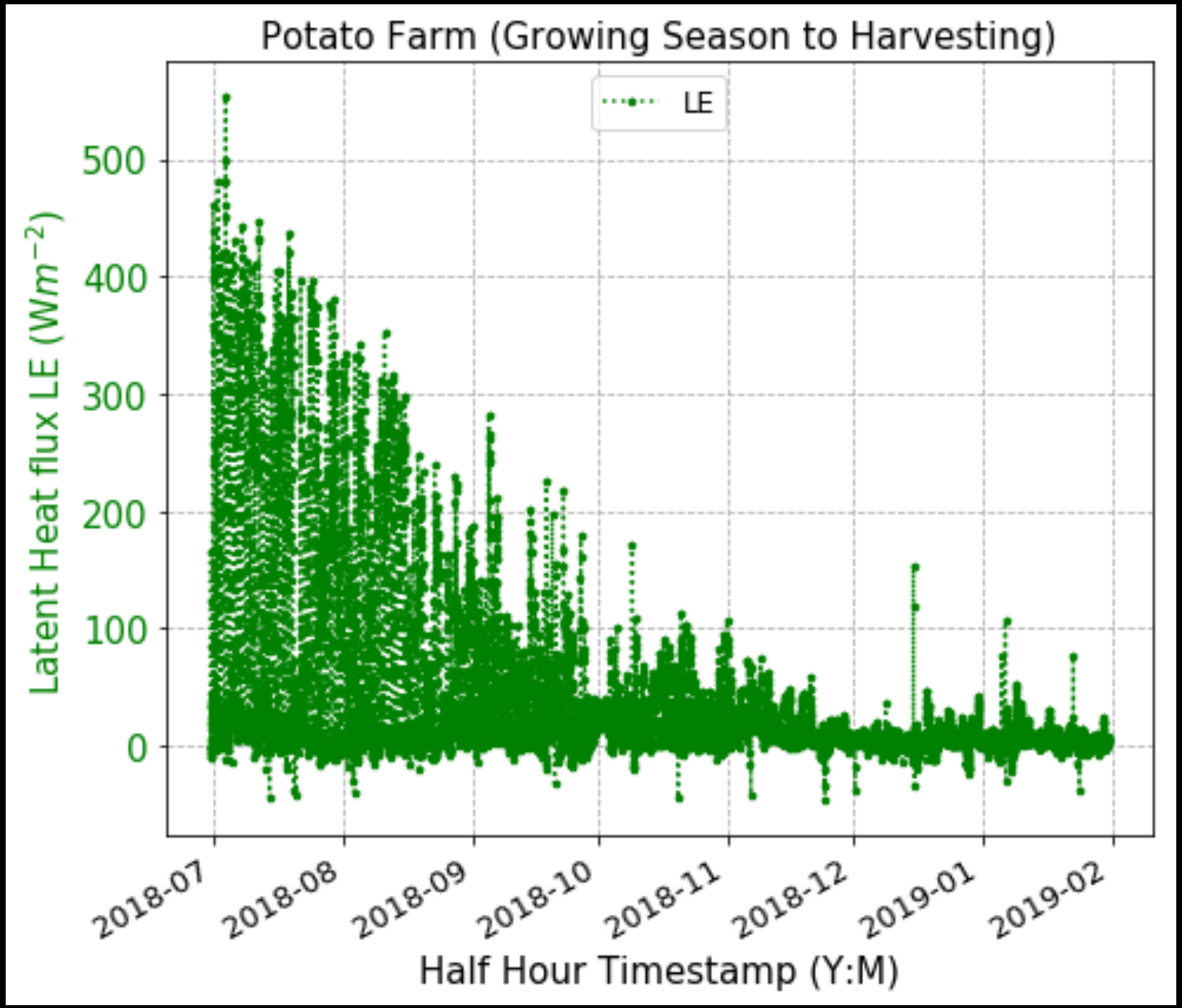
# Can we get some useful units *please*?

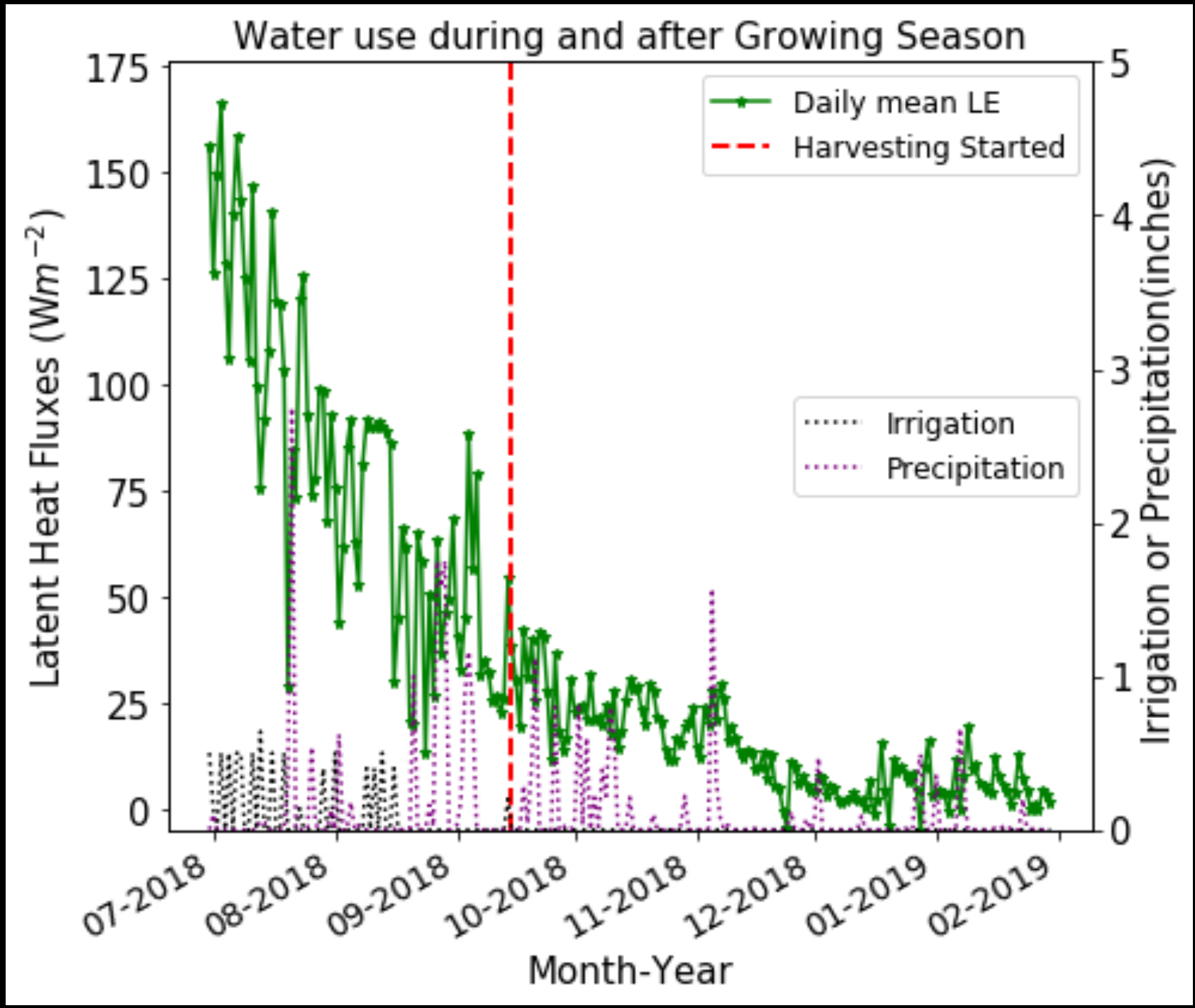
- Latent Heat Flux is measured in Watts per square meter over 30 minutes
  - 1 Watt = 1 Joule per second
  - Multiply by seconds in 30 minutes
  - Divide by latent heat of vaporization
  - Divide by density of water
  - Convert meters to inches
  - Sum values up to a time step we care
- Now we get evapotranspiration (ET) in inches per hour or day
- Yay!

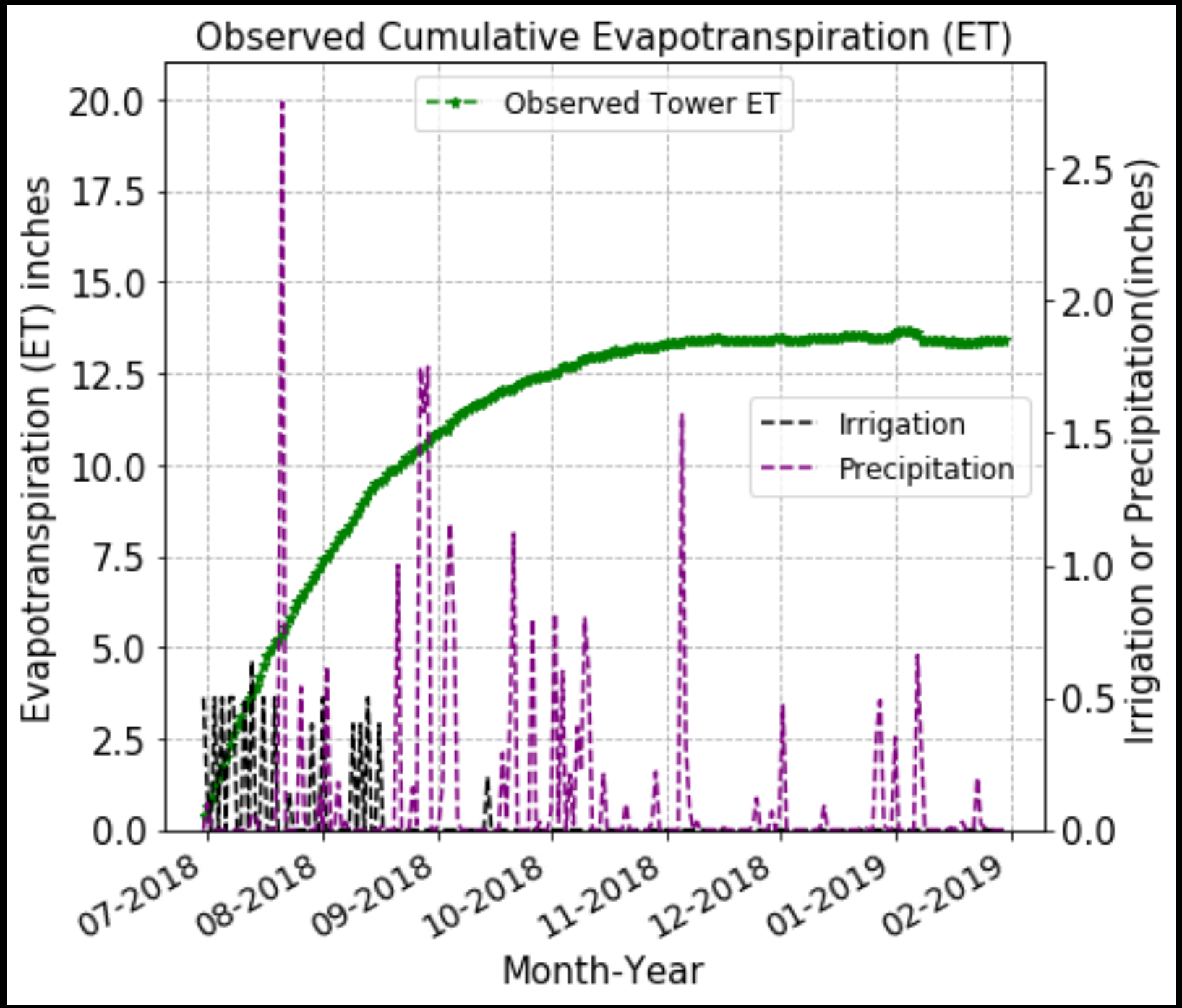


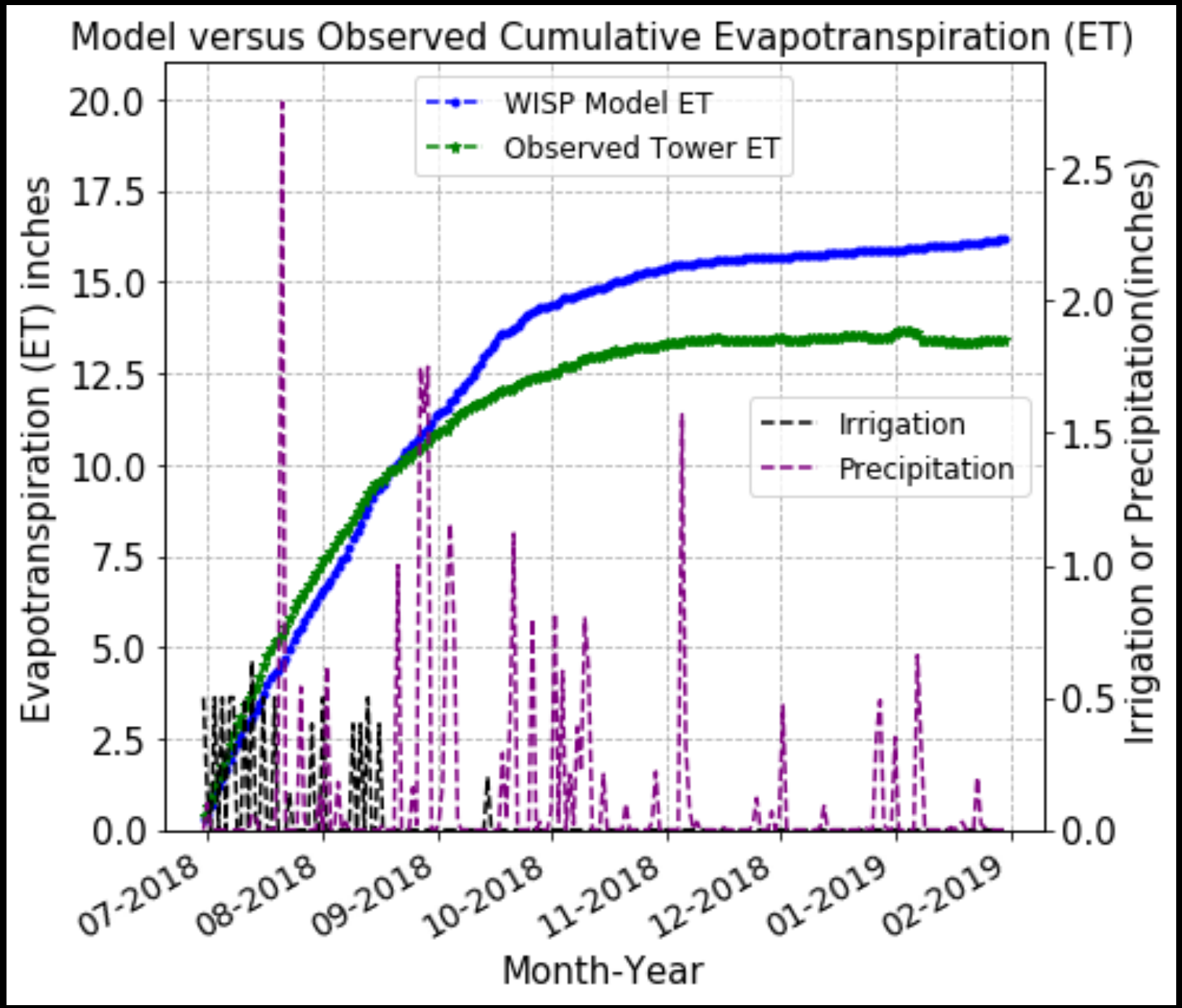

Maximum water loss right after solar noon

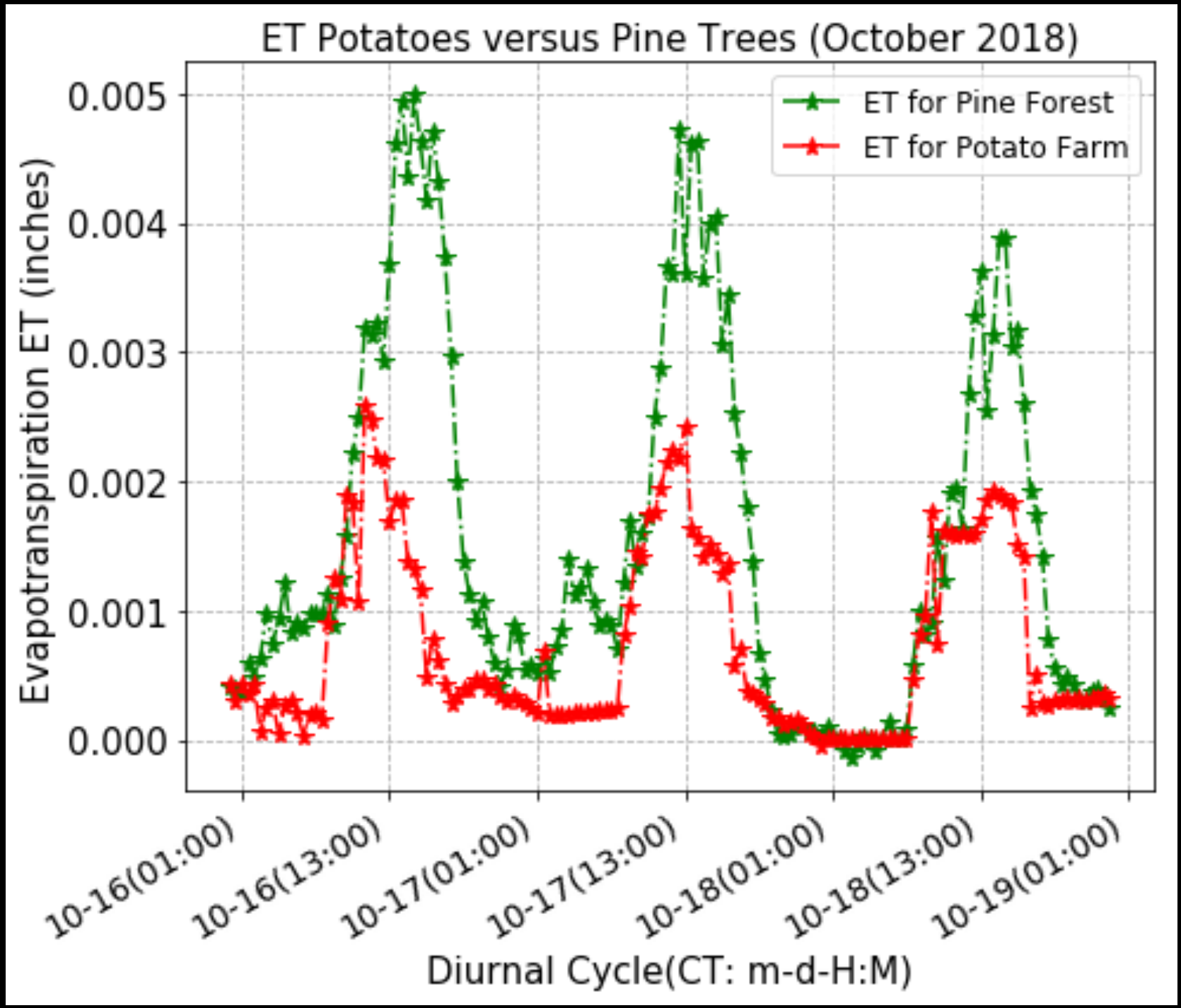

Potato Farm in August 2018 (Before and After Irrigation)
Irrigation
ET
Irrigation (inches)
Evapotranspiration ET (inches)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.000
0.002
0.004
0.006
0.008
08-16
08-17
08-18
08-19
08-20
08-21
Diurnal Cycle (Month-Day)


Potato Farm (Growing Season to Harvesting)
LE
500
400
300
200
100
0
Latent Heat flux LE ($Wm^{-2}$)
2018-07
2018-08
2018-09
2018-10
2018-11
2018-12
2019-01
2019-02
Half Hour Timestamp (Y:M)


Water use during and after Growing Season
Daily mean LE
Harvesting Started
Irrigation
Precipitation
Latent Heat Fluxes (Wm$^{-2}$)
Irrigation or Precipitation(inches)
Month-Year
175
150
125
100
75
50
25
0
5
4
3
2
1
0
07-2018
08-2018
09-2018
10-2018
11-2018
12-2018
01-2019
02-2019


Observed Cumulative Evapotranspiration (ET)
Observed Tower ET
Irrigation
Precipitation
Evapotranspiration (ET) inches
Irrigation or Precipitation(inches)
Month-Year
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
2.5
2.0
1.5
1.0
0.5
0.0
07-2018
08-2018
09-2018
10-2018
11-2018
12-2018
01-2019
02-2019


Model versus Observed Cumulative Evapotranspiration (ET)
WISP Model ET
Observed Tower ET
Irrigation
Precipitation
Evapotranspiration (ET) inches
Irrigation or Precipitation(inches)
Month-Year
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
2.5
2.0
1.5
1.0
0.5
0.0
07-2018
08-2018
09-2018
10-2018
11-2018
12-2018
01-2019
02-2019


ET Potatoes versus Pine Trees (October 2018)
ET for Pine Forest
ET for Potato Farm
Evapotranspiration ET (inches)
0.005
0.004
0.003
0.002
0.001
0.000
10-16(01:00)
10-16(13:00)
10-17(01:00)
10-17(13:00)
10-18(01:00)
10-18(13:00)
10-19(01:00)
Diurnal Cycle(CT: m-d-H:M)

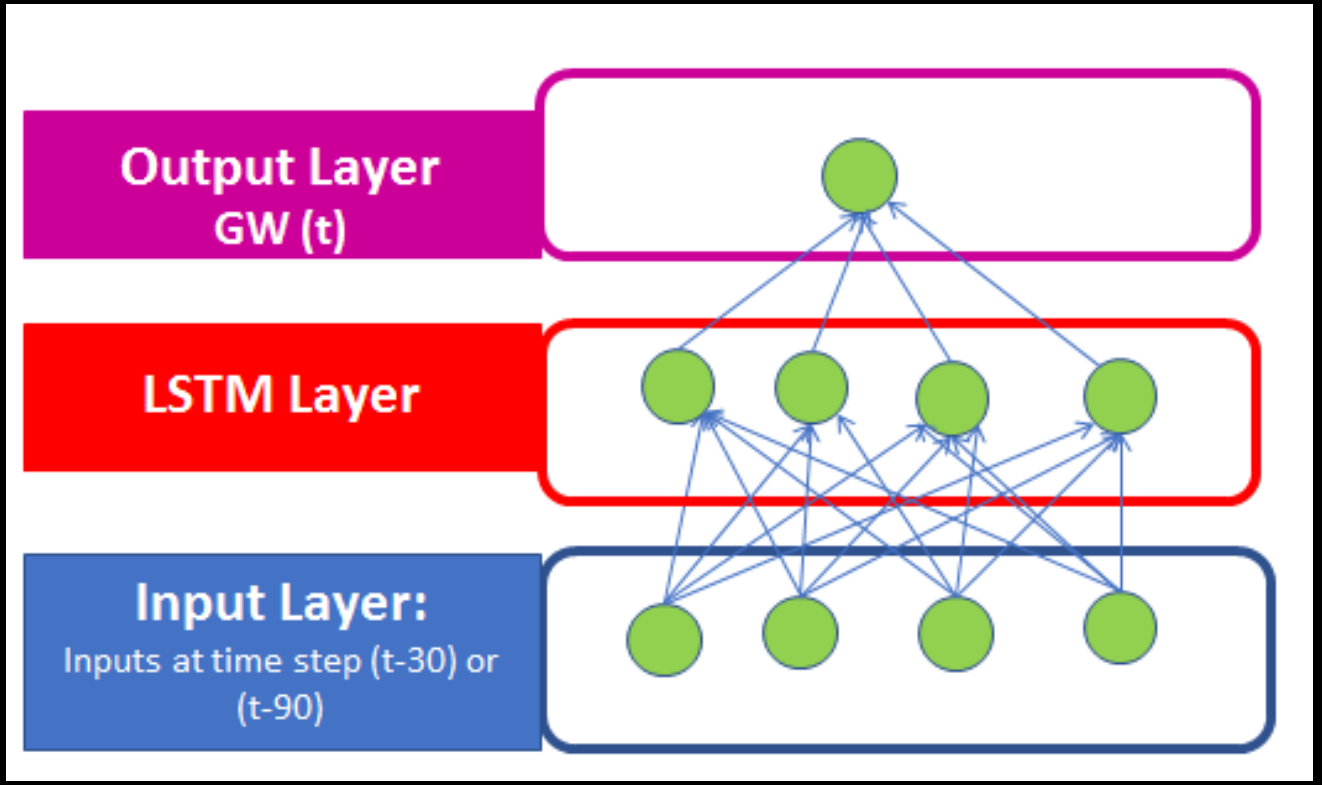
# Can machines “learn” ET?

# Forecasting of GW depth with help of Neural networks

**Model Inputs:**

- GW (t-90)
- Max Air Temp (t-90)
- Min Air Temp (t-90)
- Precipitation (t-90)
- PDO (t-90)

**Model Output**
GW (t)

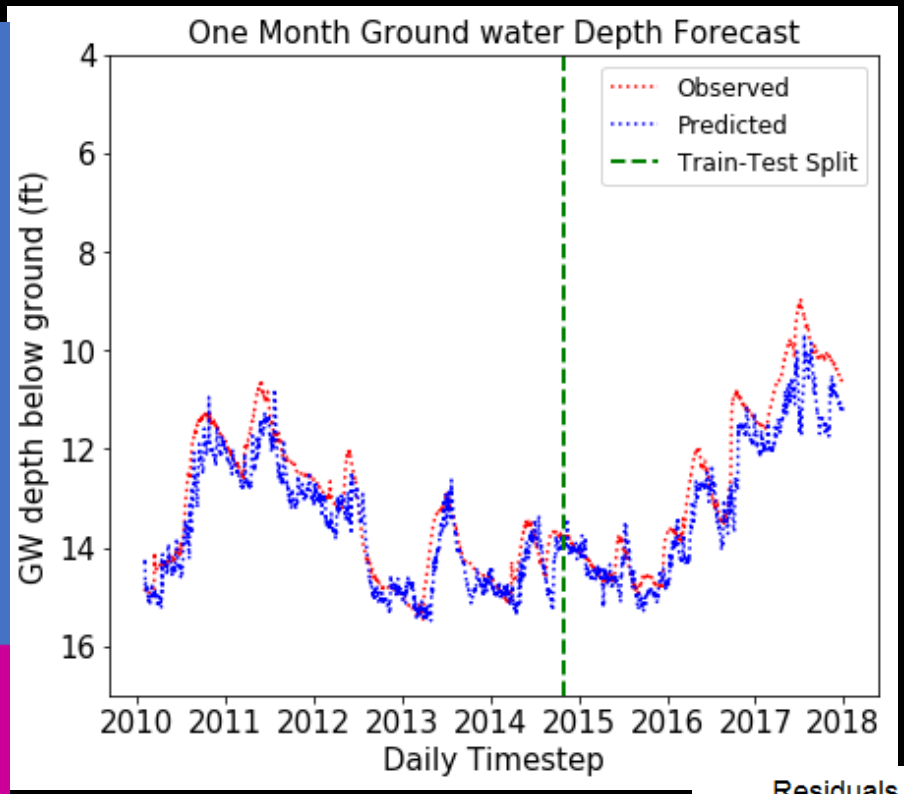


## Model Inputs for one month Forecast:

- GW (t-30)
- Max Air Temp (t-30)
- Min Air Temp (t-30)
- Precipitation (t-30)
- PDO (t-30)
- Soil Moisture (t-30)
- Soil Temperature (t-30)
- Relative Humidity (t-30)
- Net Radiations (t-30)

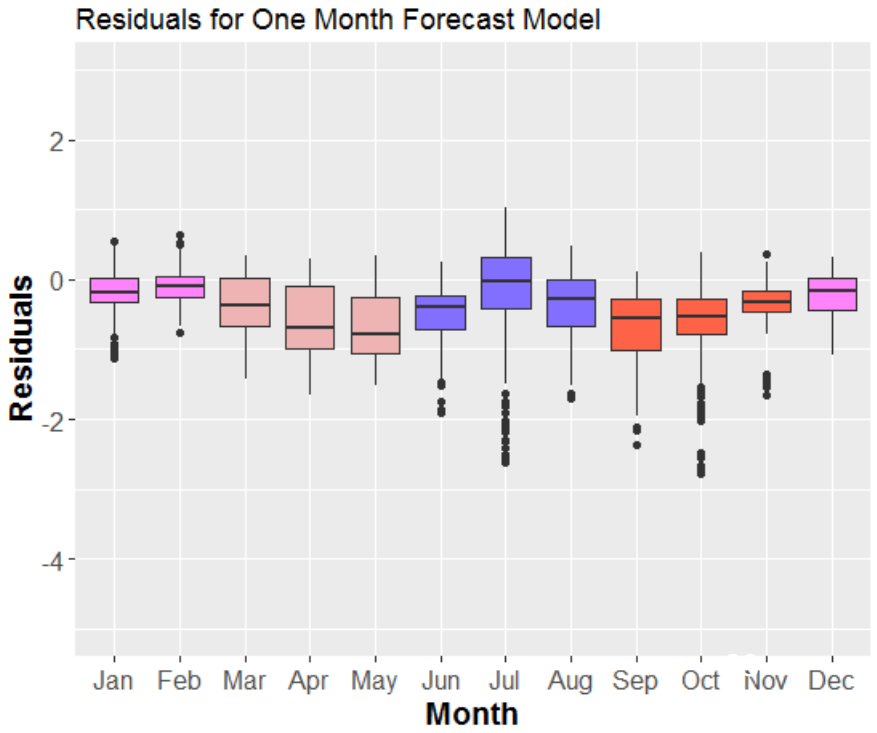
## Model Output

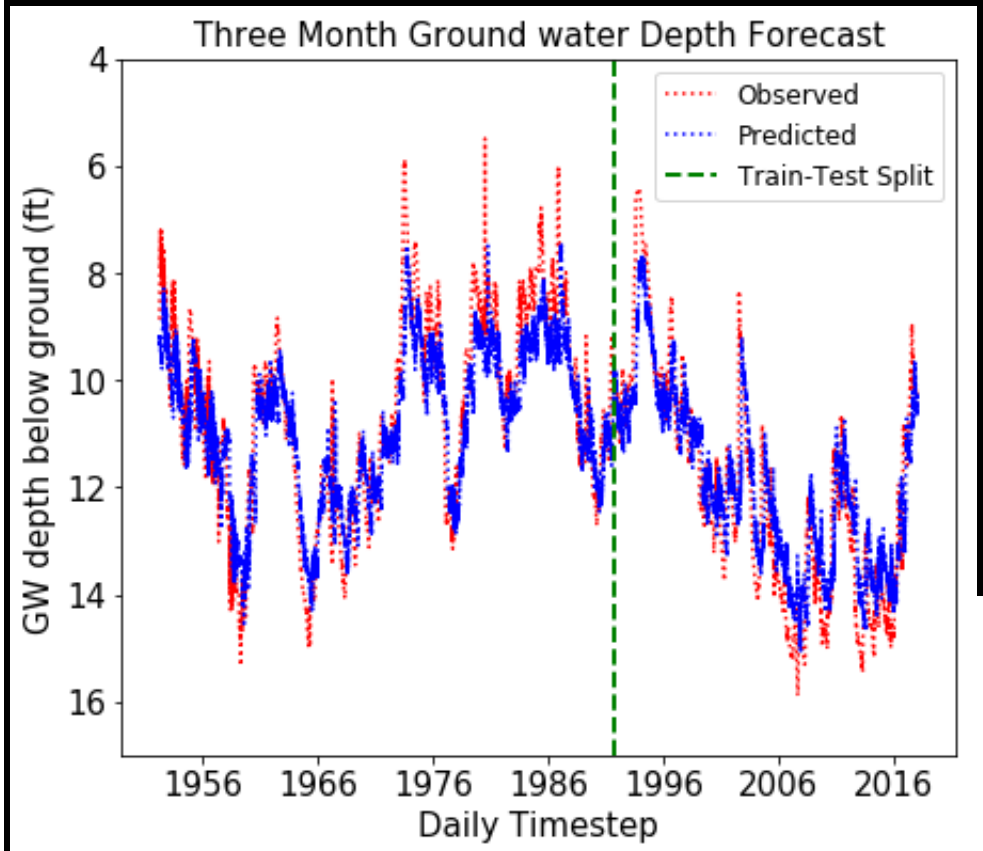
GW (t)




**Training Period : 2010-2014**

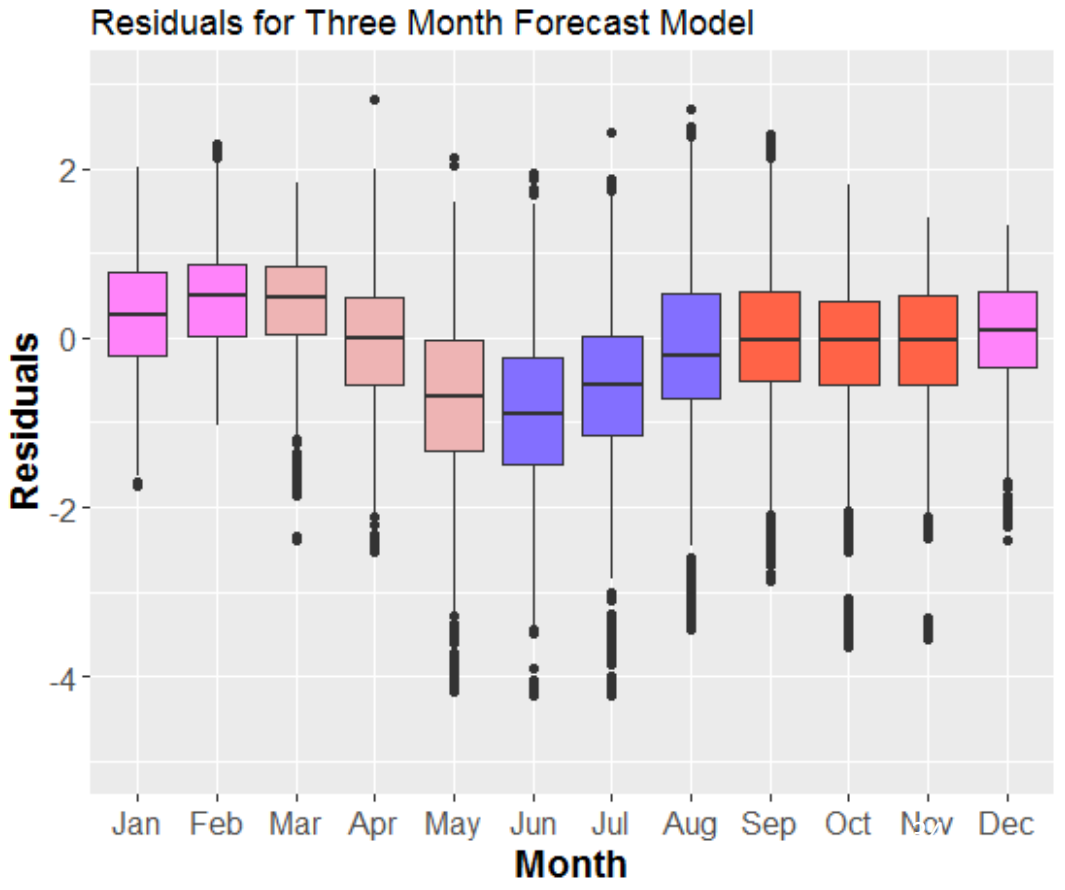
**Testing Period: 2015-2017**






Lower GW depth means shallower GW

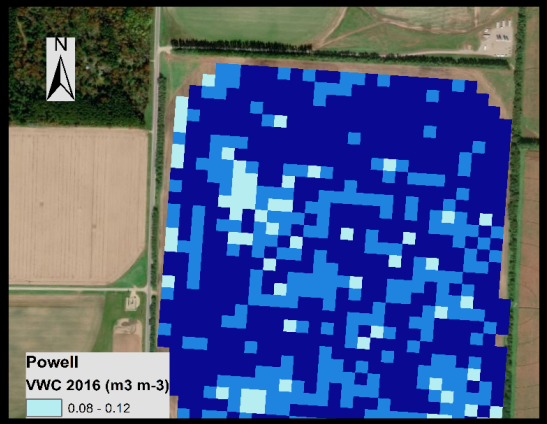
**Residuals= (observed-simulated)**

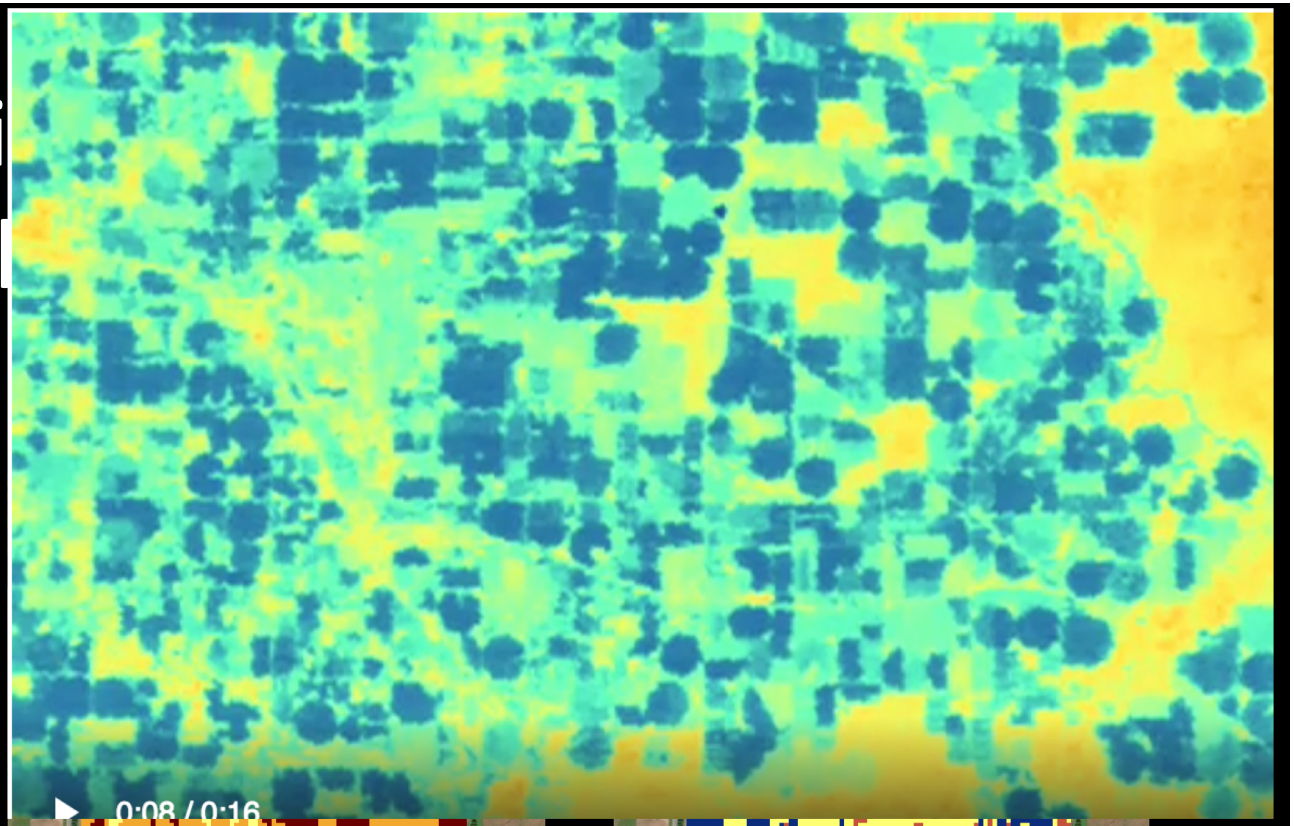


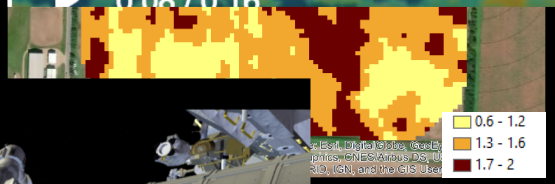
# Looking to the future

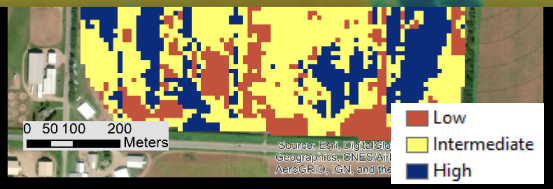
# Within-fi
# Soil

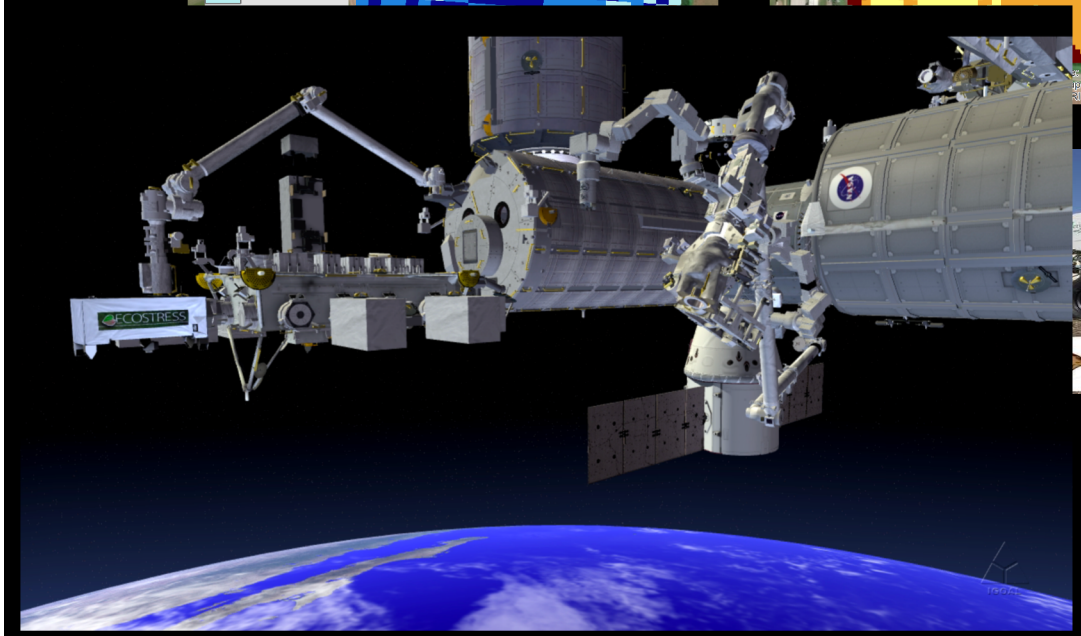
Mean VWC-2016



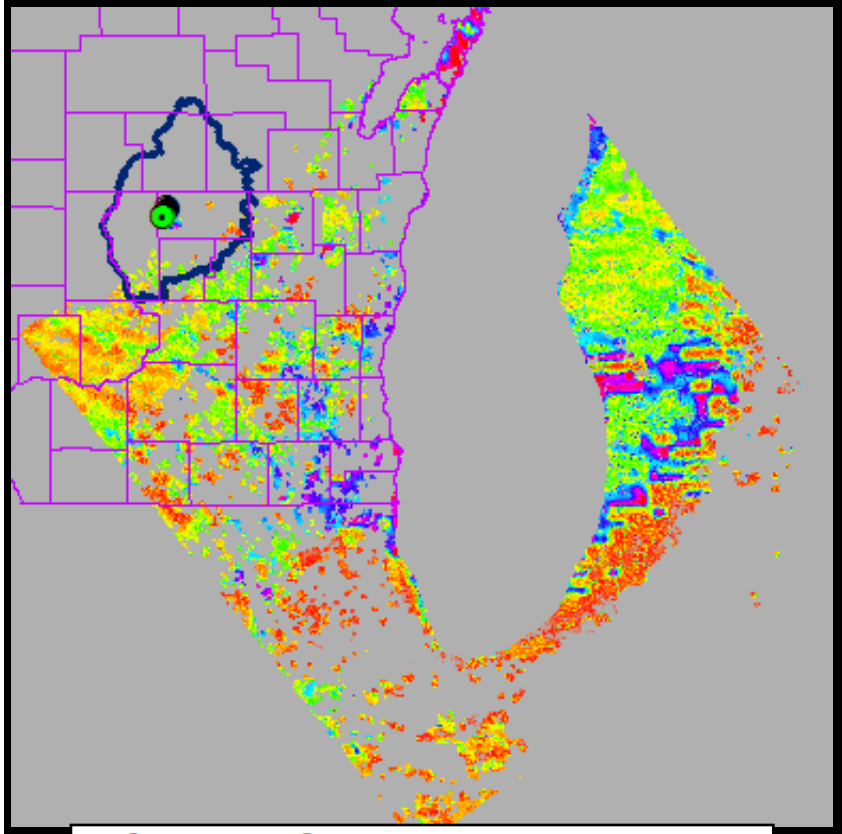




Jingyi Huang, UW-Madison Soil Science
+ NASA JPL

Water use Efficiency (WUE)=GPP/ET

More WUE less ET



**Legend**

- Potato EC Tower
- Pine EC Tower
- WCS Boundary

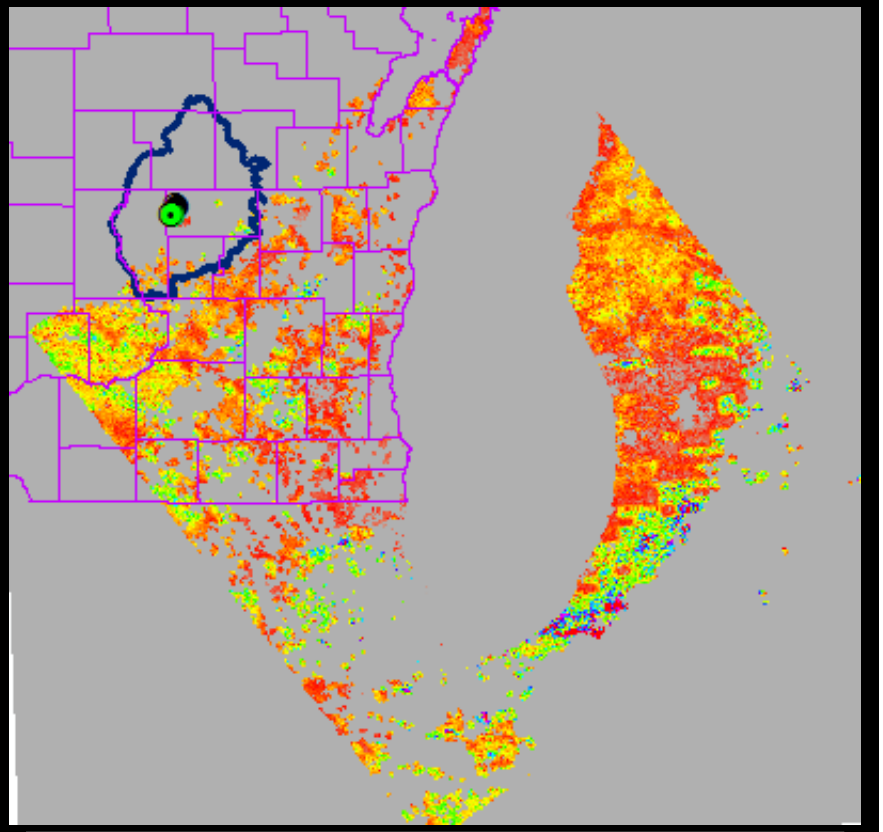
**Ecostress Daily ET(inches)**

**Value**

High :15.2

Low : 0.86

8th August 2018



**Ecostress WUE (g C kg-1 H2O)**

**Value**

High : 20.1591

Low : 0

# Thank you

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**University of Wisconsin Graduate School**